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THE MOON'S ORBIT AS AN ELEMENTARY EXERCISE.

JOHN CHARLES DUNCAN.

Laboratory work as a part of the course in elementary descriptive astronomy given at Wellesley College was inaugurated many years ago by the first director of the Whitin Observatory, Professor Sarah F. Whiting. Her plan of devoting about a third of the student's time to this part of the work is still followed, and in recent years a number of new exercises have been introduced. One of these, which has been found valuable in several ways, is that of determining the moon's apparent path and its geocentric orbit from simple original observations. A method of plotting the moon's apparent path among the stars from observations with a cross-staff is described in "Laboratory Astronomy", by R. W. Willson, Chapters II and V, and has been used by Professor Willson and his associates in Harvard University for a number of years. A few years ago the exercise was extended at Harvard by measuring the moon's semi-diameter with a device of Professor Willson's invention, and plotting the geocentric orbit by the method suggested for the earth's orbit in Young's Manual of Astronomy, Art. 159. When the exercise was given this year at Wellesley, measures of the diameter of photographs of the moon were substituted for the visual measures.

Determining the Moon's Apparent Place.

The moon's apparent place in the sky is determined by observation with the cross-staff. This, one of the simplest and most primitive of astronomical instruments, consists of a straight stick about a meter long upon which slides a cross-piece or head. When one end of the stick is placed near the eye, the distance of the cross-piece from that end is proportional to the cotangent of half the angle subtended by the cross-piece; hence, the angular distance between two objects, as the moon and a star, may be observed by making the cross-piece cover the arc of the celestial sphere between them when the end of the staff is held near the eye. The cross-staffs used at Wellesley were made by

Mr. D. W. Mann, of Cambridge, Mass., with aluminum cross-pieces of the form shown in Figure 1. The length of the longer part is 20 centimeters and its width 2.5 cm., while the shorter part has a length of 10 cm., and a width of 5 cm. By using these different dimensions, the

FIGURE 1. ALUMINUM HEAD OF CROSS-STAFF.

observer is thus provided with the equivalent of four different cross-pieces. The staffs are graduated to read directly in degrees. With such an instrument, one can measure arcs of from 2° to 30° with an average error of only a few tenths of a degree.

FIGURE 2. USING THE CROSS-STAFF.
Drawn by Charlotte B. Abbott.

For the exercise about to be described, the distance of the moon from at least two—usually three or more—known stars was measured on each clear night during October and November, 1918. The distance observed was that of the star from the moon's bright limb, and this was reduced to the center by adding or subtracting the moon's semi-diameter (¼ degree). For an accurate determination of the moon's position, it is important that no two stars used on the same night be nearly on the same great circle with the moon, and the most favorable condition is obtained when the moon and two of the stars form a right triangle with the moon at the right angle. Each student in the beginning astronomy class observed the moon in this way on at least six different nights. On nights when the moon was visible only after midnight, observations were made by one of the instructors, and no clear night in the months of October and November was lost. Typical observations, selected from the list, are shown in Table I. The time given is "winter" Eastern standard time—5 hours less than G. M. T.

TABLE I. CROSS-STAFF OBSERVATIONS OF LUNAR DISTANCES.

Oct. 19, 6:45		°	Nov. 8, 6:00		°	Nov. 22, 17:00		°
	α Arietis	11.9		β Capricorni	22.3		Procyon	16.8
	β Andromedae	24.3		λ Aquilae	17.2		Pollux	18.9
	γ Pegasi	23.1		η Serpentis	20.5		Regulus	21.9
Oct. 21, 7:30			Nov. 10, 6:00			Nov. 24, 14:00		
	ζ Persei	11.9		Altair	26.6		δ Leonis	21.4
	α Arietis	25.4		β Aquarii	15.1		Regulus	6.7
	η Tauri	3.9		δ Capricorni	15.6		ζ Hydrae	19.3
Oct. 23, 10:00			Nov. 12, 6:00			Nov. 26, 16:30		
	Aldebaran	20.0		β Aquarii	14.0		γ Virginis	14.8
	Capella	25.6		δ Capricorni	15.4		Denebola	18.7
	β Tauri	10.0		α Aquarii	7.4		ν Hydrae	17.7
Nov. 7, 5:30			Nov. 14, 6:00			Nov. 29, 17:00		
	σ Sagittarii	12.4		β Andromedae	33.2		γ Hydrae	12.1
	ν Ophiuchi	13.0		γ Pegasi	9.8		Spica	10.2
	η Serpentis	20.7		α Pegasi	19.8		Arcturus	35.5±

PLOTTING THE MOON ON THE MAP.

For plotting the moon's place among the stars, we used Willson's ecliptic map, which shows the principal stars within 30° of the ecliptic together with their coördinates in both the equator and ecliptic systems. This map is printed without star names or symbols, and accompanied by a list of stars giving magnitudes, right ascensions and declinations, from which the dot representing any given star may be readily found.

To plot the position of the moon, the student opens a compass to a distance corresponding to the measured lunar distance, as found on a scale of degrees printed on the map, places the steel point on the dot representing the star, and draws an arc of a circle; when this is repeated, using the other stars measured on the same night, the intersection of the arcs indicates the place of the moon. When three or more stars are used, the effects of parallax and of errors of observation often become apparent by the failure of the arcs to intersect at the same point; the center of the little triangle formed by the arcs is then taken as the moon's place. Plate XVIII shows the observations of Table I plotted on the ecliptic map.

From the work done up to this point, the student may derive the length of the sidereal month, the longitude of the moon's nodes, and the inclination of the orbit to the ecliptic.

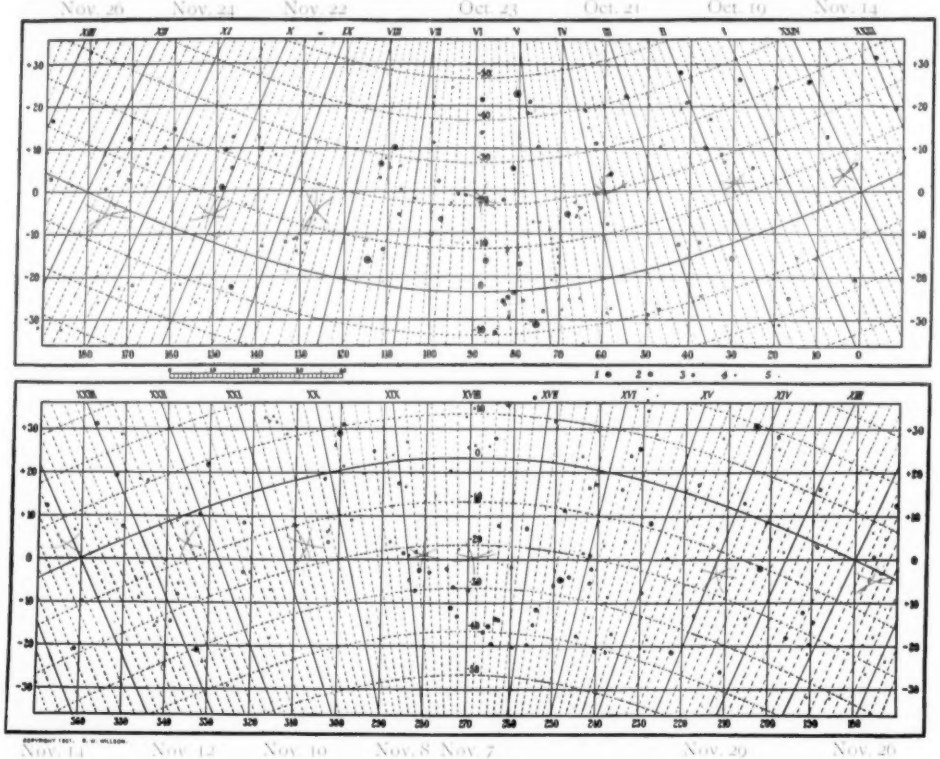
The Photographs.

On each of the nights when the moon was observed with the cross-staff, it was also photographed with the 12-inch refractor of the Whitin Observatory, by the use of a yellow screen and orthochromatic plates. Twelve of these photographs, made on the same nights as the observations of Table I, are reproduced in Plate XVII. Each student in the class was given a set of these photographs, printed on their original scale on a sheet of 8x10 double-weight Cyko. They are very useful in studying lunar topography, and a comparison of the position of certain markings with respect to the limb on different dates—for example, that of the crater Gassendi on October 19 and October 21—shows well the effect of libration in longitude. In this exercise, however, the photographs were used simply for finding the change of apparent diameter as the moon moved around its orbit.

Representation of the Geocentric Orbit.

The student now forms a table like Table II, giving (1) the date of observation, (2) the moon's longitude as read from the ecliptic map, (3) the diameter of the photographic image in millimeters, and (4) the quantity $\frac{k}{d}$, where d is the above diameter and k a convenient constant, say 4000. For finding the last quantity quickly, the Wellesley class was provided with a short table giving $\frac{4\,000}{d}$ for values of d differing by 0.5 mm and extending from 42 mm to 50.5 mm.

PLATE XVIII



THE MOON'S APPARENT PATH.

TABLE II.

Date	λ	d	$\frac{4000}{d}$
	°		
Nov. 14	4	48.8	82.0
Oct. 19	29	49.9	80.2
21	59	49.1	81.4
23	88	47.7	83.8
Nov. 22	127	46.0	87.0
24	152	44.8	89.3
26	176	43.6	91.8
29	212	42.5	94.1
7	269	43.0	93.0
8	281	44.0	90.9
10	308	45.9	87.2
12	336	47.8	83.7

Following the method described in Young's Manual of Astronomy, Art. 159, the student next draws a "spider" with straight legs radiating from a dot representing the earth and making angles equal to the longitudes of the moon with a line that represents the direction of the vernal equinox. The geocentric position of the moon is represented by laying off along the spider's legs distances in millimeters equal to $\frac{k}{d}$. A circle drawn through these positions represents very nearly the moon's geocentric orbit, or rather its projection upon the plane of the ecliptic. The center of the orbit is most easily found by laying over the "spider" a circle of about 85mm radius drawn on transparent paper, and placing this circle so that it is as nearly as possible equidistant from all the positions marked for the moon; the center of this circle is marked on the drawing by piercing through with a pin or compass point. A circle drawn around this center with the proper radius will pass near all the positions of the moon, but usually not exactly through them, due to errors of measurement and to the perturbations of the orbit. An orbit drawn in this way from the data of Table II is shown in Figure 3.

The student may now find the eccentricity of the orbit (ratio of distance earth to center to radius of orbit), the longitude of perigee and the dates of perigee passage. From the date and moon's age given with each photograph, it is possible to derive the length of the synodic month.

The elements of the orbit that have been derived from Plates XVII and XVIII are as follows:

Longitude of ascending node	257°
Longitude of descending node	58°
Inclination	4°
Longitude of perigee	37°
Dates of perigee passage	Oct. 20, Nov. 16
Eccentricity	0.08

As usually happens in the solution of this problem, the difference obtained by subtracting the longitude of the descending node from that of the ascending exceeds 180°. Probably the chief reason for this is the fact that no correction for parallax was applied to the observations

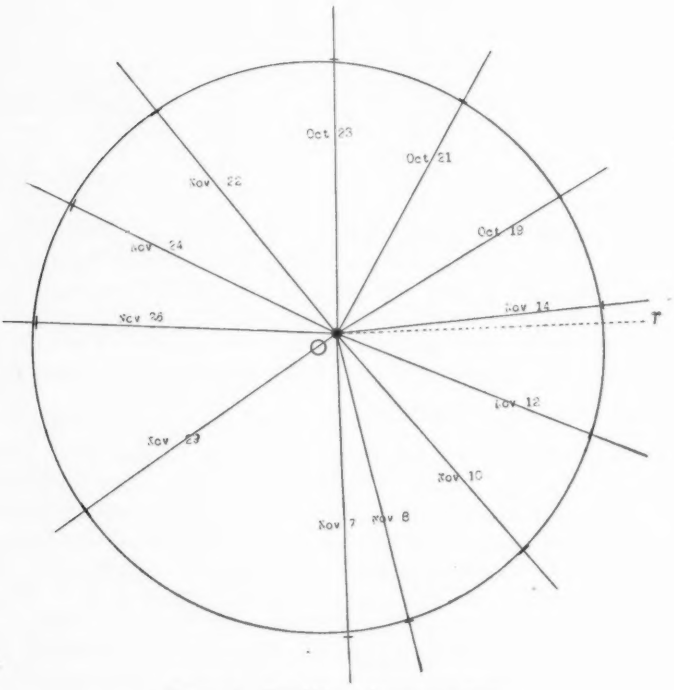


FIGURE 3. THE MOON'S GEOCENTRIC ORBIT.

made with the cross-staff. The effect of parallax in our latitude is always to throw the moon too far south; this produces too large a value for ☊ and too small a value for ☋. The eccentricity found from Plate XVII is larger than that found by accurate methods. This may be partly accounted for by the fact that the moon chanced to be near apogee at the time of new moon. On the photographs of the thin crescent the cusps were lost through underexposure, with the result that the measured diameter of these photographs was too small and the corresponding geocentric distance of the moon too great. Moreover, no correction for "augmentation" was made, and this correction was least for the crescent moon, photographed always at a low altitude.

The advantages of this exercise in the teaching of elementary astronomy are of several different kinds. In addition to giving the training afforded by any kind of measurement, however simple, the observations with the cross-staff require considerable acquaintance with the brighter stars and offer an incentive for constellation study. It would be a dull student that could make such observations on a number of nights and plot them on a map without learning something of the diurnal motion of the celestial sphere, the position of the ecliptic and other circles of reference, the moon's orbital motion, and, by analogy with this last, the apparent annual motion of the sun. In working with the photographs, some knowledge of the moon's appearance in different phases is incidentally absorbed. The picturing of the lunar orbit from longitudes read from the map and measures made on the photographs brings out more clearly the meaning of the elements of an orbit than any amount of reading would do, while the fact that the orbit is determined largely from his own observations gives the student, in some measure, a sense of kinship with "real astronomers."

Whitin Observatory,
Wellesley, Mass.

THE MASS OF A PLANETOID CAPABLE OF PRODUCING A NOVA.

WILLIAM H. PICKERING.

In Popular Astronomy 1918 **26**, 599 it was suggested that the phenomena of a nova might be produced by the collision of a small dark body with a star. The name planetoid was proposed for such a roving dark object, and it was at first suggested that its mass might be one one-hundredth that of the earth. Later it was estimated that a mass not exceeding one four-thousandth would have been sufficient to produce all the effects observed. Beyond this estimate no attempt was made to compute what the actual mass of such a body would be. Such a computation cannot now be made with the facts at our disposal, but we can at least compute a definite maximum mass for the planetoid, based on the supposition that all of the light is due to the collision.

The curve Figure 1 is founded on that published for Nova Aquilae No. 3, in connection with Harvard Circular 208. The magnitudes have however been reduced to luminosities, so that the curve represents the actual brightness of the star at any given time. The abscissas give the

day of the month in June 1918, reckoned from Greenwich noon. The ordinates on the left give the luminosities in thousands, the unit being the brightness of the star before the explosion, when its magnitude was 10.5. The ordinates on the right give the corresponding magnitudes.

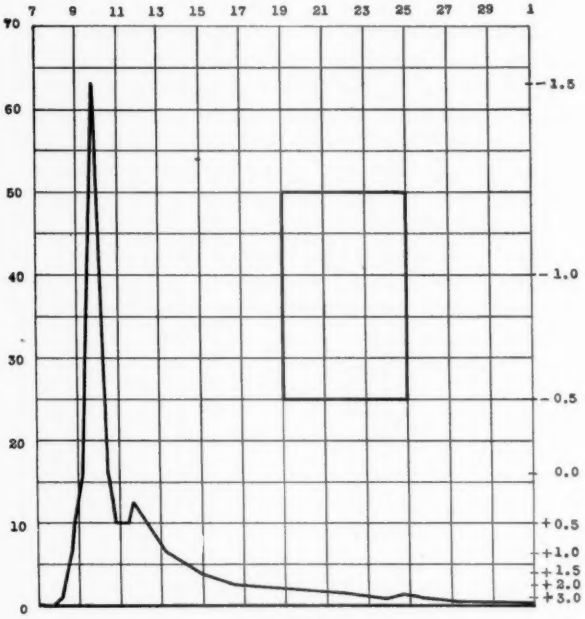


FIGURE 1.

The area enclosed between the curve and ordinate zero represents the total light given out by the star in what we call light days, where the area of one square represents 10,000 units. The total area enclosed between June 8 and July 1 amounts to 120,000 light days. Let us allow one-quarter as much more for the continuation of the curve, and call the total output 150,000 light days. This total output is represented by the rectangle. Let us now set for ourselves the problem of determining the mass of the colliding planetoid, moving at the parabolic speed of 400 miles per second, which would be capable of increasing the light of our sun 150,000 times, and maintaining it at that figure for a period of one day.

According to the *American Ephemeris* the semi-diameter of the sun is 6.95×10^8 meters. Its area is therefore 6.07×10^{18} square meters. According to Young (General Astronomy § 346) the sun emits 1.3×10^5

horse power per square meter of its surface. The total horse power of the sun therefore, considered as a motor is 7.89×10^{23}.* In order to maintain 150,000 times the light of the sun we must furnish power at the rate of 1.18×10^{29} h. p., or 6.51×10^{31} ft. lbs. per sec. At the time of its maximum brilliancy the nova must have been delivering power at a rate of this order of magnitude.

The energy of a body moving 400 miles a second, expressed in ft. lbs., is the product of the mass into the square of the velocity, divided by 64, or 6.96×10^{10} M. In order to last for one second at the above mentioned rate, such a mass M must weigh 4.68×10^{17} tons. To last a day it must weigh 4.05×10^{22} tons. The mass of the earth is 6.0×10^{21} tons. The computed mass of the planetoid is therefore 6.72 times that of our earth, and if of the same density, its diameter would be 15,000 miles.

The above computation it will be remembered is based on the supposition that all of the light of the nova is due to the collision. In the original paper above mentioned, however, it is shown that this is by no means the case, but that a very large proportion of the light is due to the explosion caused by the collision, and is therefore due ultimately to the stored energy of the star itself. What proportion of the total light is due to the collision we have no means whatever of knowing, and it doubtless varies with the glancing character of the blow, as well as the temperature and viscosity of the star, but it is clear that even if the star itself furnished none of the added light, a very brilliant nova could be caused by a collision with a dark planetoid of less than twice the diameter of our earth, a body extremely small as compared to the star. If one-tenth of one per cent of the light were due to the collision, and the remainder to the explosion, the diameter of the planetoid would been 1500 miles, and its mass 1/150 that of the earth.

Mandeville, Jamaica, B. W. I.
January 7, 1919.

* By means of a carbon filament we can produce 300 candle power per horse power. By using a tungsten filament, which permits of the use of a higher temperature, we can produce 600 c.p. per h.p. According to the Harvard Annals **61**, 69 the total candle power of the sun is 4.38×10^{27}. The sun therefore furnishes us with 5550 c. p. per h. p.

BRIEF DESCRIPTION OF 26-INCH EQUATORIAL INSTRUMENT OF THE NAVAL OBSERVATORY AND ACCESSORIES—CLARK MOUNTING AT OLD OBSERVATORY, WARNER AND SWASEY MOUNTING AT NEW OBSERVATORY.

ASAPH HALL.

[Communicated by Rear Admiral T. B. Howard, U. S. N., Superintendent, Naval Observatory.]

This instrument was mounted at the old site of the Naval Observatory in 1873.

The framework of the drum of the dome was of timbers, outside and inside coverings being attached to the timbers and forming an air chamber in the walls of the drum. The framework of the revolving dome was also of timbers, covered on the outside with galvanized iron and on the inside with canvas. The slit was 6½ feet wide and extended 6 feet beyond the zenith. There were at first wooden shutters for the slit, but it finally became difficult to move them, and they were replaced with canvas. After some years the timbers of the drum and dome spread, so that a small gas engine was installed for turning the dome.

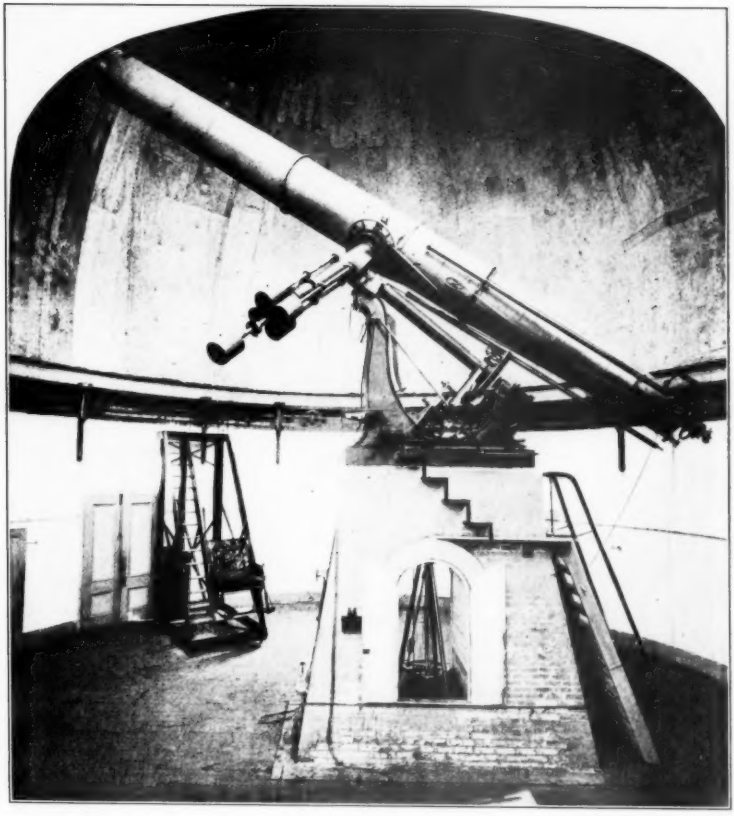
But the observing room was easily ventilated, and the observations were made under good conditions.

The floor of the dome was fixed, so that observations were taken from observing chairs.

The instrument pier above the ground was of brick, having an arch in the cellar to contain the driving mechanism of the driving clock, and an arch in the observing room for the governor. The clock was moved at first by a Barker's wheel, to which the city water was applied directly. As the water pressure was found to be unsteady a Huygens loop and a weight were substituted for the direct action of the water wheel, the clock being driven by the weight and the water wheel automatically winding up the weight after it had fallen the proper distance.

The governing was performed by a single conical pendulum which closed a circuit when the clock ran fast, so that a brake was pressed against the outer rim of the heavy horizontal fly wheel. There was

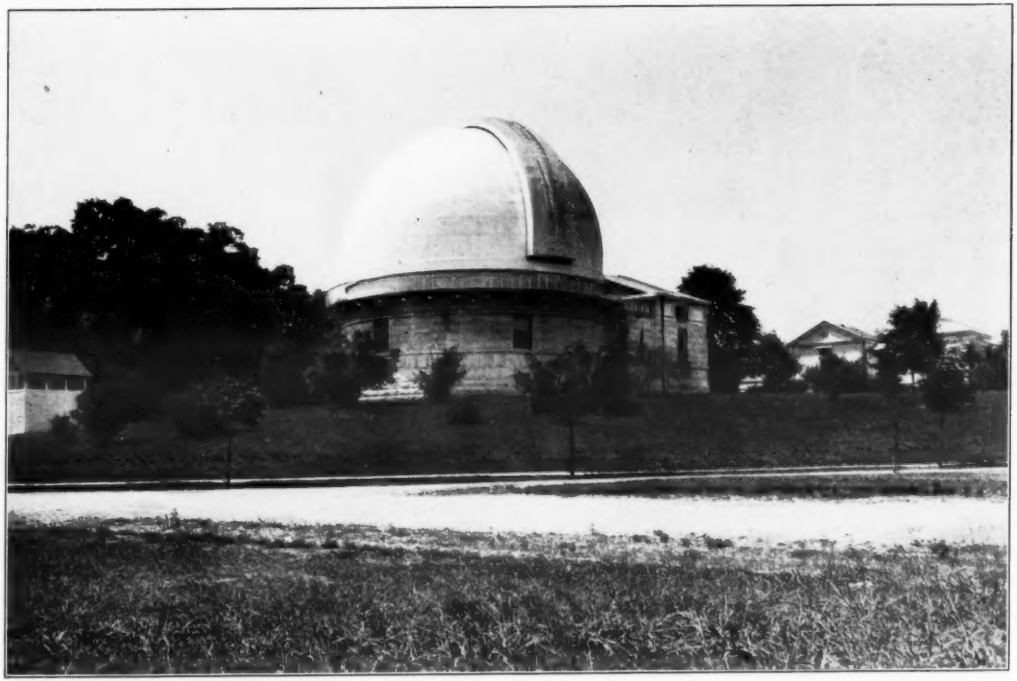
PLATE XIX



ORIGINAL MOUNTING OF 26-INCH EQUATORIAL

By Alvan Clark & Sons, governor of driving clock, observing chair, interior of old dome.

PLATE XX



NEW DOME OF 26-INCH EQUATORIAL, U. S. NAVAL OBSERVATORY.

Two office rooms on the north side. Dome by Warner & Swasey; architect of building, Richard Morris Hunt.

considerable trouble with the driving clock until the Naval Observatory instrument maker changed the form of the lower end of the rotating vertical shaft to that of a spherical surface of large radius, also, making the shaft rotate on a plane, horizontal, agate surface.

The motion of the clock work was transmitted to the polar axis through a sector, as was usual with the Clark mountings. The sector ran for about two hours. After the change in the vertical shaft of the governor just mentioned a satisfactory and smooth driving motion was obtained.

On the top of the brick pier of the instrument was a stone cap on which rested the cast-iron harp-shaped support of the instrument. This piece was probably too light in the case of the Washington mounting. In later instruments the Clarks made these pieces heavier.

The slow motions in right ascension and declination of the old 26-inch mounting were communicated by ropes, there were not convenient arrangements for reading the fine circles, there was no bright field illumination, and the bright wires were illuminated by a lamp held in the hands of an assistant, the light passing through a slit in the micrometer box opposite the head of the micrometer screw.

The micrometer screws furnished by the Clarks were excellent, as shown by the investigations of them printed in the Naval Observatory volumes. The slide carrying the threads moved by the micrometer screw consisted of two flat brass pieces of equal length attached at right angles to a short brass piece. The micrometer box served as a bearing for the screw and the short brass piece as a nut. The end of each of the long arms of the slide was attached to a spring, against which the screw worked. This forked shaped arrangement of the micrometer slide appears unsound, although the writer cannot find real evidence that error was introduced thereby.

Now, the old Clark mountings seem rather rough, but they were easily handled, and on the whole efficient.

The 26-inch objectglass was refigured by the Clarks at the Naval Observatory in 1876.

The Naval Observatory was moved to the new site on Georgetown Heights in 1893, at which time a new mounting was constructed for the 26-inch equatorial by Warner & Swasey, as well as an elevating floor and dome by the same firm.

The old Clark mounting was set up at the new site in a frame building, to carry a pair of 10-inch photographic lenses constructed at the Naval Observatory.

The walls of the dome for the new 26-inch mounting are of brick faced with rough white marble. With care as to ventilation the observing conditions can be kept good. The proper method of building a

drum would be to set up in concrete vertical steel beams to carry the track of the revolving dome, the beams to have an outside and inside covering, making a double wall for the drum, which then could be easily ventilated.

The elevating floor has a rise of twelve feet. It is worked by four hydraulic rams moved by the city water and reinforced from a tank of compressed air. The floor has given little trouble. The moving parts are cared for by the engineer of the Observatory heating plant, and require perhaps six days' work per year. At very infrequent intervals the packing of the controller gets out of order, so that it is not possible to stop the floor in its upward motion, and it moves up against the iron brackets on the walls. For about two days in each winter it is necessary to shut off the water from the rams, to prevent freezing.

The steel dome is well constructed and is moved easily, either by means of a hand rope or a small eletric motor. Cork paint has been applied to the inner surface of the dome to prevent moisture condensing on it.

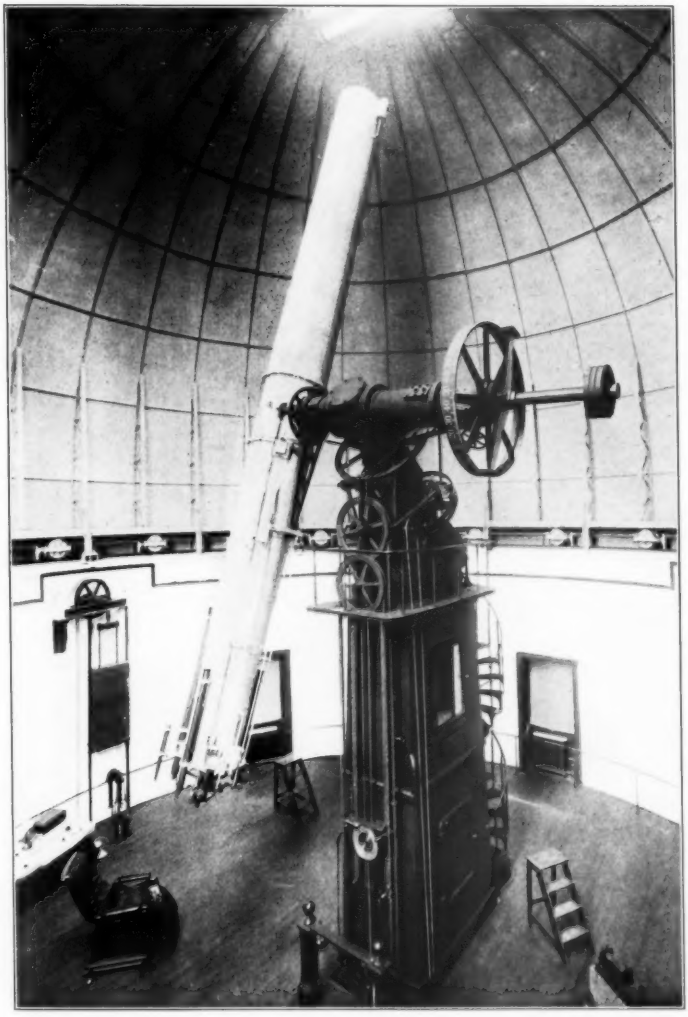
The new mounting is easily handled by means of the gear ropes. It is very steady (see tables of instrumental constants in the reports of the Superintendents of the Naval Observatory, also in the Observatory volumes and in the Astronomical Journal). The differential flexures are small. The torsion in position angle was 0°.015 until the Repsold micrometer was attached to the instrument. After that, on account of the increased weight, the torsion was increased to 0°.025.

The principal defect of the new mounting is that the driving clock has periodic errors. These errors have been reduced in amount by the Naval Observatory, by scraping the bevel gear wheels. Also this mounting is constructed to be used always over the pier. When used under the pier there is a slight slip of the declination spindle. There is no adjustment for this slip. Apparently there should be thrust bearings for each end of the declination spindle, with an adjustment for slip.

The fine declination and hour circles have verniers read by microscopes. The hour circle readings are carried by an ingenious arrangement to microscopes attached to the setting dial, which moves on vertical slides. It is believed that the fine circles should be retained on all large instruments. Low power micrometer microscopes should be substituted for verniers.

The micrometer built in connection with the new 26-inch mounting is constructed in an unusual manner. The screw does not work against a spring, but by means of a hardened steel block is pushed against a shoulder on the screw, which shoulder bears against the inside of the micrometer box. The slide carrying the wires moves as a nut on the

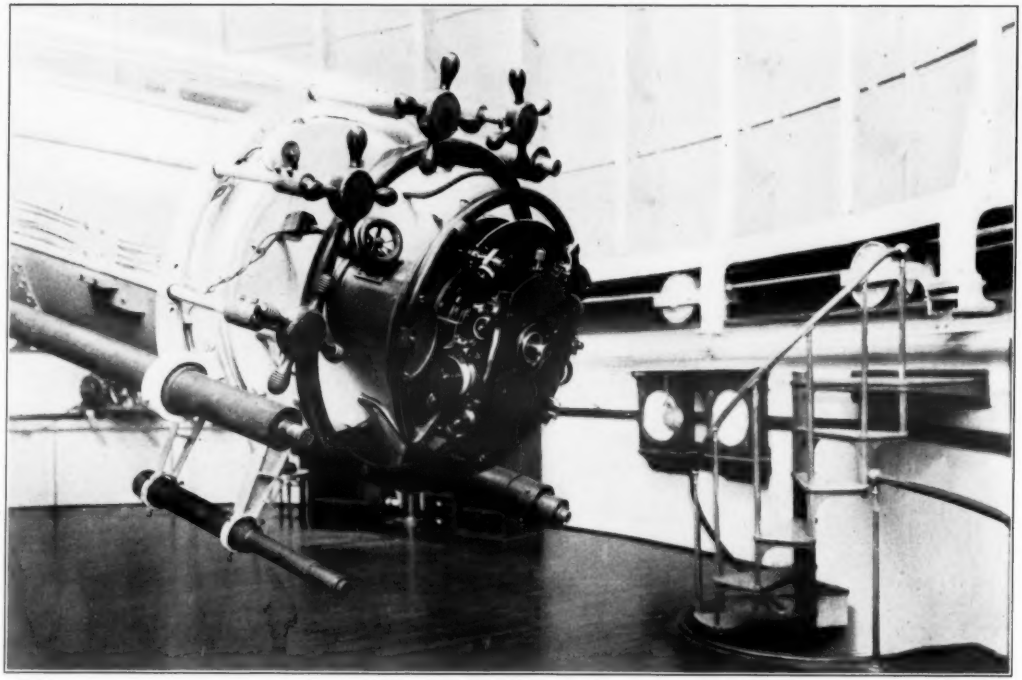
PLATE XXI



New Mounting of 26-inch Equatorial

By Warner & Swasey, interior of new dome, elevating floor. Optical parts as on the original instrument.

PLATE XXII



Eye-end of New Mounting,

Repsold micrometer, 5-inch finder, 2-inch finder, microscopes for reading declination circle, clamps and slow motions in hour angle and declination. Floor raised 12 feet.

screw. The bright wire illumination is not satisfactory. The screw is a good one.

Since the erection of the new 26-inch mounting the following additions have been provided by the Naval Observatory:

Contact rings, to carry current for small lamps on the micrometer and at the circles, also for the chronograph circuit and for the satisfactory bright field illumination installed by this observatory. This bright field illumination proceeds from a lamp near the eye end, the light from which is thrown by a prism against the object glass, by which it is reflected to the field.

Finer gear for the declination slow motion, so as to increase the accuracy of the determinations of parallel when it is taken on a long wire.

Improved illumination for the fine declination circle, so that the circle can be read accurately.

New micrometer, having symmetrical bright wire illumination, and all the most modern arrangements for making micrometric measures of the highest degree of accuracy.

HALLEY'S COMET 1910.

MAXWELL HALL.

The comet was well seen in Jamaica between May 14 and 22, and full notes were forthwith sent to the Royal Astronomical Society, which appeared in the *Monthly Notices*, Vol. LXX, p. 615. The observations were not discussed, and no explanation was then offered as to what occurred between the 18th and the 22nd. It is here proposed to discuss those observations, and if possible to draw a plan showing the projection of the tail of the comet on the plane of the ecliptic at the different times of observation.

The places of observation were all between longitudes $5^h\ 4^m$ and $5^h\ 11^m$ west of Greenwich, so that the Greenwich mean times corresponding to 4 a.m. and 7 p.m. local time are 21^h and 12^h respectively: and to avoid confusion it is proposed to adhere to Greenwich mean time throughout. Thus the observation made May 14, 4 a. m. local mean time, will be changed to May $13^d\ 21^h$ G.M.T; and the observation made May 20, 7:30 p. m. local mean time, will be changed to May $20^d\ 12^h$ G. M. T.

May 13^d 21^h. The head and tail were well seen; the latter was straight as on previous mornings, and it extended to θ Pegasi, the central line being 1° south of that star; and taking the position of the head from an ephemeris, the length of the tail was 46°. This showed considerable increase in length, and gave promise of a great display as the comet approached the earth.

May 15^d 21^h. A very fine display; the head was brighter than a star of the first magnitude; the tail was straight, about 3° broad throughout its length, or nearly so, and of a silvery white color; it extended to a point a little south of the small group of stars 68 to 71 Aquilae; so that its length was 80½°.

Now Halley's comet belongs to the class having straight tails, and it was to be presumed that the tail on this occasion was shot out from the head away from the sun in the direction of the radius vector produced, and somewhat inclined upwards; for the latitude of the end of the tail was about 10° more than the latitude of the head, as was indeed the case May 13^d 21^h, so that apparently the tail would pass above the earth May 18^d 16^h,* when the comet would pass through its descending node, and the sun, comet, and earth would be all in one straight line.

From earlier observations it appeared that the axis of the tail was not only straight but that the tail itself was cylindrical; but if we assume that the tail was cylindrical May 15^d 21^h its axis, though apparently straight, would be no longer truly so, but curved somewhat backward and concave to the earth, so that its apparent angular diameter was about the same throughout the length of the tail.

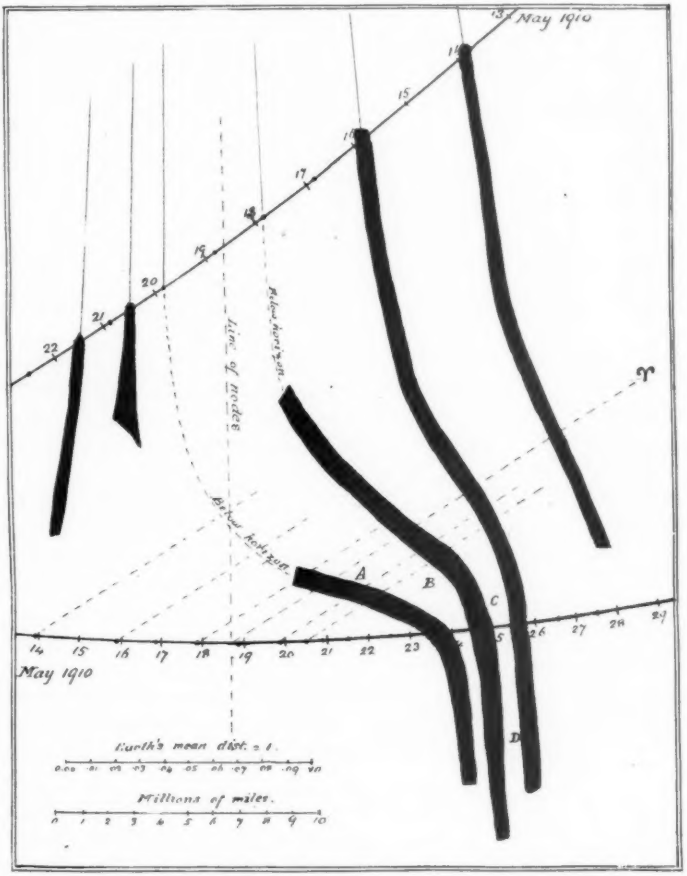
This curvature may be of use in explaining why the tail did not pass over the earth May 18 or 19; and a constant cylindrical thickness will enable us to judge of the distance of different points in the tail where the angular breadth was observed, and to draw a plan of the projection on the plane of the ecliptic, however roughly.

Assuming, then, that the tail was cylindrical but curved, it was about 14 million miles from the earth May 15^d 21^h, so that the linear diameter was about 730,000 miles.

May 16^d 20^h. The tail extended to the same group of stars, and was about 87° in length. At θ Pegasi its angular breadth was 3½°; and as the tail had advanced two million miles towards the earth since the preceding morning its distance was now twelve million miles, and the linear diameter of about 730,000 miles had remained unchanged.

* The central axis of the tail would be 520,000 miles above the earth; and taking the diameter of a cross section of the tail to be 730,000 miles, the lowest part of the tail would be 155,000 miles, above the earth.

May 17^d 21^h. The comet had increased in splendor; its tail nearly reached the Milky Way about 3° north of κ Aquila; but its head was at this time below the horizon, and not more than 8° from the sun, so that it could not be seen at any time that morning. The length of tail actually seen was about 103°; but computing by means of an ephemeris, the angle subtended at the earth between the head and the end of the tail was 113 °.



PLAN OF THE ORBITS OF HALLEY'S COMET AND THE EARTH.

The angular breadths at θ and γ Pegasi were 4° and 5° respectively, and it now becomes necessary to refer to the plan or projection of the orbits of the earth and comet on the plane of the ecliptic.

The short cross lines on the orbits show the positions of the earth and comet at the Greenwich mean noon for each day; the round dots show their positions when the different observations were made; the lines drawn upward from the head of the comet are parts of the projected radii vectores; and the dotted lines drawn from the earth towards the First Point of Aries allow geocentric longitudes to be marked down.

TABLE I.

1910 May G.M.N.	The Sun		Halley's Comet *			
	Geoc. Long.	Log. rad. vect. of earth	Geoc. Long.	Geoc. Lat.	Log. rad. vect.	Log. distance from earth
d	° ′		° ′	° ′		
14	52 48	0.0047	20 19	+5 58	9.8952	9.4618
15	53 46	0048	25 2	+5 17	9027	4086
16	54 44	0049	31 12	+4 22	9102	3501
17	55 41	0050	39 11	+3 5	9176	2945
18	56 39	0051	49 38	+1 15	9250	2388
19	57 37	0051	62 40	−1 0	9323	1993
20	58 35	0052	76 37	−3 40	9396	1873
21	59 32	0053	92 22	−5 46	9468	1993
22	60 30	0.0054	105 20	−7 23	9.9540	9.2387

Table I gives the information necessary for plotting the positions of the earth and comet; and Table II gives the geocentric longitudes and latitudes of the head of the comet, the end of the tail, and of the points where its apparent angular breadth was estimated, all for the different times of observation.

Referring again to the plan, the tail May 13^d 21^h was slightly curved for the sake of symmetry; the tail May 15^d 21^h was curved in accordance with the assumption; the tail May 16^d 20^h was omitted to avoid confusion; and the tail May 17^d 21^h was drawn in accordance with the assumed constant diameter of about 730,000 miles. The result is surprising, and shows a repulsive action by the earth on the tail of the comet. Observations were made that morning of the breadth at two different points along the axis, and whatever the cause may have been which curved the tail May 15^d 21^h and May 16^d 20^h that cause was now greatly increased, and can only be attributed to the action of the earth.

May 18^d 20^h. A few hours before this time the head of the comet passed across the disc of the sun, so that the tail would have greatly changed its position since the last observation had it not been curved backward from the earth; but in consequence of this curvature it had much the same position as before; it was broader and dimmer, and it

* Taken from Dr. Crommelin's ephemeris.

reached as far as the Milky Way where the end was lost. Between ϵ and θ Pegasi its angular breadth was 6°. But the sky clouded over, and not much more was done.

TABLE II.

1910 May G.M.T.	Head		End of tail		Angular breadth of tail			Notes
	Geoc. Long.	Geoc. Lat.	Geoc. Long.	Geoc. Lat.	Geoc. Long.	Geoc. Lat.	Breadth	
d hr	°	°	°	°	°	°	°	
13 21	20	+6	336	+16	—	—	—	
15 21	30½	+4½	308	+14	0	+12	3	Near. γ Peg.
16 20	38	+3	310	+16	336	17	3½	At θ Peg.
17 21	48½	+2	294	+18	8	12	5	" γ "
"	"	"	"	"	336	17	4	" θ "
18 20	60½	− ½	288	+17	333	20	6	Between ϵ and θ Peg.
19 21	75	−3½	289	+20	38	15	17	" α Arietis and γ Andr.
"	"	"	"	"	10	20	15	" γ Peg. and α Andr.
"	"	"	"	"	326	21	7	" ϵ Peg. and α Equulei.
20 12	84½	−4½	97½	− 3	—	—	—	
21	90½	−5½	300	+29	39	20	19	" γ Andr. and α Arietis.
"	"	"	"	"	352	+25	9	" α and μ Peg.
21 12	99	−6½	127	− 7	—	—	—	

The tail has not been drawn on the plan, in order to avoid confusion; but the distance from the earth of the point where the breadth was 6° was about 7 million miles.

May 19^d 21^h (20d 4 a. m. E. S. T.). A magnificent display; notes were made of the position of the tail among the stars, and even of the points where it cut the dim horizon; a large drawing was subsequently made, of which a reduced copy is here given, from which the width of the tail at different points can easily be measured; and assuming that the linear diameter still remained unchanged, the different distances of the points can be computed.

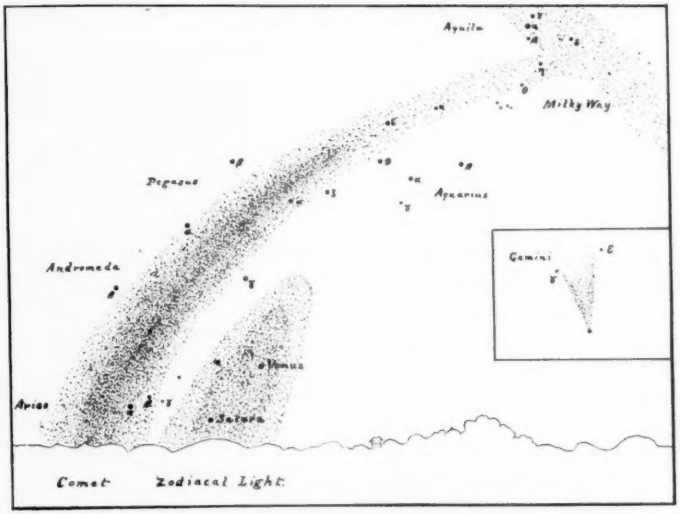
The resulting projection of the tail on the plane of the ecliptic confirms the remarks made respecting the projection May 17^d 21^h. The sun seems to have crowded down the tail towards the earth, and the influence of the earth is more apparent in driving away the tail at right angles to the action of the sun; and at a considerable distance from the earth the sun's action was again undisturbed.

The length of tail seen above the horizon was 117°; but the linear length of the part seen was small compared with that seen May 15^d 21^h, or with that seen May 17^d 21^h, supposing that the part below the horizon was connected with the head.

May 20^d 12^h. (20d 7 p. m. E. S. T.). Having obtained leave of absence from my official duties at Chapelton, I had to stop the night at Montego Bay on my way to my observatory at Kempshot; and

that evening I saw the comet in the western sky about 7 p. m. local time. A sketch was made, which was inserted as an inset in the large drawing of the comet as seen that morning; the fan-shaped tail was about 13° in length, and its greatest transverse width was 6°. There was no appearance of any tail below, or of any connection with the tail seen in the east that morning May 19^{d} 21^{h}. There was moon-light, the moon being between its first quarter and full moon.

Now new moon occurred on May 9, so that all the early morning observations were made when the sky was dark before dawn; but we have now to consider moon-light rather carefully.



HALLEY'S COMET, 1910 MAY 20, 4 A. M. and 7:30 P. M.

It might be supposed that moon-light and twilight cut off the connection between the tail seen in the early morning May 19^{d} 21^{h} and the head and tail seen in the evening 15 hours later; but if we look at the plan it is evident that the action of the earth would have been to break that connection; and there can be no doubt that the part of the tail seen May 19^{d} 21^{h} had drifted away from the head under the repulsive influence of the earth.

May 20^{d} 21^{h}. After the moon had set this morning I saw the band of light in the east, or what was left of the former tail. It was faint and broad; its breadth from γ Andromedae to α Arietis was 19°, while its breadth between α and μ Pegasi was 9°. If we are still able to

assume that the linear diameter had remained unchanged, the tail would then have the position on the plan marked by the letters A, B, C, D.

May 21^d 12^h. The comet and the new tail were well seen at Kempshot this evening; and there was no connection with the old tail.

May 21^d 21^h. At Kempshot this morning a glow was seen above the northeast horizon, between the Milky Way and the Zodiacal light; but as there was an interval of only 5 minutes between the setting of the moon and the commencement of dawn, nothing more could be done. However the part of the tail between C and D had disappeared, and the part near B only was left; this probably dissolved away before the following morning, but moon-light prevented any observation being made.

At the Kempshot Observatory the usual telescopic drawings and micrometric measures were made of the head and nucleus, but they have no particular interest; the new tail took a long time to increase, and it was not until May 30^d 14^h that its length of 25 million miles was equal to its length May 15^d 21^h.

The above explanation and remarks are given for what they may be worth; at the time I supposed that the whole tail had been driven away from the head by the solar action, but the assumptions necessary were untenable; and the single assumption now made that the tail retained its linear diameter between May 15^d and 19^d points to the conclusion that the earth exerted a repulsive force, which first drove away the part of the tail nearest the earth, and then broke the connection after the head of the comet had passed the line joining the sun and earth.

Jamaica, April 13, 1918.

AN AMATEUR'S EQUATORIAL.

CLARENCE E. WOODMAN, Ph. D., Sc. D.

It is thought that a description of a home-made equatorial mounting for a small telescope, which can be set up on an ordinary camera-tripod, may be of interest to some of the readers of "POPULAR ASTRONOMY."

The making of this mounting occupied some of my leisure time of the last month; and its working has proved very satisfactory indeed.

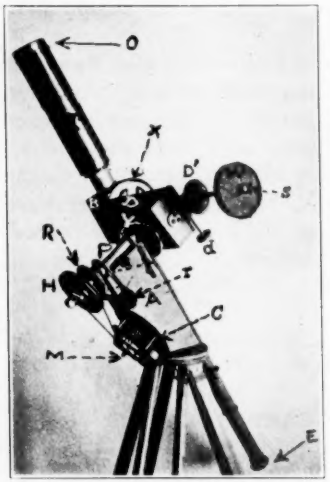
The principal "ingredients" are two blocks of well-seasoned maple, 2x3 inches, shaped with saw and plane—the lower block (carrying the polar axis) being about 9 inches long, and the upper block (supporting

the declination axis) about 6 inches long. The connections are strong bolts and screws. The gears and brass-work and clamps were purchased from a local supply house. The driving clock is the skeleton of an ordinary alarm clock, i.e. the "works" only—divested of case and face and hands.

This mounting, when fixed to a stout tripod (such as is furnished for large "view" cameras), and properly "orientated," does quite good service for star-following; and, with a little help from the slow-motion screws, serves well for observations of the planets and the moon—and (with the dark shade on the higher-power eye-piece) for the sun also.

A reference to the accompanying cut will, it is hoped, make the following description clear:

T T is the telescope, held by friction in the felt-lined box *B*, with a hinged and hooked cover.



A is the block (of hard maple—as is the declination block)—carrying the polar axis *P*. This block is bevelled, where it is fastened to the tripod, so that the angle (at *a*) is equal to the latitude of the place of observation. (In my case this is 38°, but the arrangement will serve for a degree or so either north or south.) Of course this bevel can be changed to suit any latitude. This polar axis *P* is a bicycle hub, moving in ball bearings.

C is the driving clock. A cord connects the minute-hand arbor *M* to the grooved pulley *H*, the latter so sized that the polar axis moves at the proper rate. (This construction has since been replaced—for greater accuracy—by a pinion on the minute-hand arbor, containing 15 teeth, meshing with a large wheel on the polar axis, containing 360 teeth; so that 24 revolutions of the former equal 1 of the latter.) The clock is, of course, regulated to keep sidereal time.

D is the declination block; carrying the telescope at one end, and the counter-weight *W* on the other. This counter-weight is of lead, poured into the cover of a baking-powder can.

The two graduated circles—for right ascension and declination respectively—(made from ordinary brass "protractors") are indicated by *Y* and *X*. Each has its "pointer" for setting.

E indicates the eye-piece of the telescope. There are two of these—one of 35, and the other of 55 magnification-diameters.

O indicates the two-inch objective.

There are "slow-motion" screws to both axes; the milled screw head for right ascension is shown at *r* (a little to the left of *A*)—its screw meshing with the

wheel R. The screw head for slow motion in declination is seen at d—meshing with the gear wheel D'. There are releasing-clamps for both R and D'—to free the telescope when it is to be moved by hand.

S is a "capstan" screw-head, to adjust the counter-weight.

There is a nut inserted in the center of the bottom of the block A, for fastening the mounting to any photographic tripod.

The telescope is a very good French-made instrument, from Aloe and Co., St. Louis;—2-in. aperture and 36-in. focus.

The whole arrangement is very light and portable and at the same time rigid enough (when properly placed) for any kind of work to which a small telescope is suited.

Newman Hall, Berkeley California,
April 10, 1919.

THE GEGENSCHEIN OR COUNTERGLOW.

E. E. BARNARD.

In looking over Volume 2 of the Publications of West Hendon House Observatory, Sunderland, England, (published in 1902) in connection with some auroral records, I find a long series of observations of the position of the Gegenschein or Counterglow, by Mr. T. W. Backhouse. There are 149 observations covering the period from 1871 to 1895. I had seen Mr. Backhouse's paper on this subject in Monthly Notices of the R. A. S., Vol. 36, for Nov. 1875, pp. 46-48, but did not know of his more complete series. The mean of his 149 observations of the position of the Gegenschein agrees closely with the results of my early observations in POPULAR ASTRONOMY, Vol. 7, p. 169, 1899, as will be seen by the comparison:

Backhouse	long. G − long. ☉ = 179°.50,	lat G = + 0°.78 (149 obsns.)
Barnard	= 179 .55,	= + 0 .62 (81 ")

I still believe that the lack of exact opposition to the sun is due to atmospheric absorption and that the phenomenon is a purely atmospheric one, but I wish to place the information before those interested in the matter, so that they may form their own opinion of the cause of the gegenschein. My late observations in POPULAR ASTRONOMY for February 1919 give

long. G − long. ☉ = 180°.0 ± 0°.2 lat. G = + 0°.3 ± 0°.2 (10 obsns.)

Mr. Backhouse says:

> "The brighter portion of this patch of light is roughly circular and about 7° in diameter, though it has also been noticed as elliptical, with its narrow axis parallel to the ecliptic. It is possible that this brighter portion varies in form and size."

Yerkes Observatory,
1919 March 27.

THE FLASH SPECTRUM OF JUNE 8, 1918.

H. C. WILSON.

The dark lines in the spectrum of the sun are, theoretically, caused by the absorption of light of various wave-lengths in a layer of a few hundred miles depth, called the "reversing layer", lying over and in the photosphere of the sun. This layer is composed of the vapors of many substances, which although intensely hot are, because of their radiation of heat, relatively cool as compared with the gases of the photosphere below them. These vapors therefore, according to the known laws of light, absorb out of the continuous spectrum of the photosphere just those wave-lengths which they emit. At the beginning and at the end of totality of a solar eclipse there is a fraction of a second when the solid body of the moon shuts off the light of the photosphere, leaving the "reversing layer" to project by a scarcely measurable amount. At these moments the vapors of the "reversing layer" emit their own light undimmed by the intenser light of the photosphere and so the lines in the spectrum which are ordinarily dark by contrast become bright. The interval during which the lines are seen bright is so short that their apparition is called the "flash spectrum". This was observed first by Young in 1870, and it has been photographed at nearly every total eclipse of the sun since 1895.

It is necessary to distinguish between the "flash spectrum" and the "chromospheric spectrum." The latter lasts for several seconds both before and after totality, the depth of the layer called the chromosphere being from 5,000 to 10,000 miles. This layer projects so far out from the photosphere that the principal lines in its spectrum can be seen on any day, by placing the slit of the spectroscope tangent to the edge of the sun's disk.

With a slitless spectroscope at the time of the total eclipse the lines are curved, being really segments between the curve of the moon's disk and the curve of the layer of vapor over the sun. The chromospheric lines are long, those from the upper regions of the chromosphere reaching nearly half way around the lunar disk, at the moment when the edge of the photosphere disappears or reappears. The "flash" lines are short, reaching only a small fraction of the way around the moon's

disk, the length varying with the interval between the moment of exposure and the moment of the moon's contact with the photosphere.

It is difficult to get the exact moment for an exposure which will give the simple "flash". If the exposure is made a second too late after second contact or a second too early before third contact, the "flash" will not show at all; only the chromospheric spectrum will be secured. If the exposure is made two or three seconds before second contact or after third contact, the result will be a composite spectrum: a band of continuous spectrum through the center, with the "flash" and chromospheric lines running out on each side to greater or less distances according to the depths of the layers of vapors. Still earlier (or later) the middle of the band will consist of reversed lines with the continuous spectrum on either side, and beyond this the "flash" and chromospheric lines.

At the time of the total eclipse of June 8, 1918, the writer was located at Fraser, Colorado, just over the high range of mountains west of Denver, in company with Professor F. P. Leavenworth and Mr. W. O. Beal of the University of Minnesota, and Mr. John H. Darling of Duluth, Minn. The altitude of our station was nearly 9000 feet. Much snow could be seen on the mountain peaks in all directions from us, but there was no snow where we were.

The Apparatus.

Owing to the expense of transportation the writer could not take with him the 8-inch photographic telescope and cameras which were used at Southern Pines, North Carolina, in 1900, but contented himself with carrying two 60° prisms and a 2½ inch lens of about 30 inches focus. These were fitted into a box made by the college carpenter, with adjustments for focusing on all the visible part of the spectrum and a device by which the photographic plate could be dropped quickly ½ inch between successive exposures. It was thus possible to make six exposures on a 5x8 plate.

A rude polar axis was made by sawing the top of a vertical post to the slant of the meridian altitude of the equator at Denver, and bolting to this a wedge-shaped block cut so that, when turned to the proper position on the post, its upper surface was in the plane of the moon's orbit, while its lower surface was in the plane of the equator. The single bolt was put through box, block and post, perpendicular to the equator and so became the polar axis. The bolt was provided with large washers and the nut was turned tight enough to hold the apparatus in position by friction, while by using force enough to overcome the friction it could be turned to the east or west to follow the motion of the sun. The box could be turned on the wedge-shaped block for

the purpose of adjustment, but after the adjustment was made, bringing the two planes into the proper position, the box was screwed tight to the block, leaving only the equatorial turning movement.

All the pieces of the apparatus were packed in a single box, a little longer but smaller than an ordinary trunk, and so could be carried as baggage.

To mount the apparatus the vertical post was set up in one corner of the packing box and bolted firmly to the two sides of the box. A level space was prepared on the ground and covered with an inch or so of sand. The packing box was placed on this bed of sand and partly filled with rocks (sand would have been better, but there was not enough available). It was then shifted about and tilted slightly until it rested firmly on its base of sand and the post was vertical as nearly as could be determined with a carpenter's level. The direction of the meridian had been previously determined by marking the shadow of a narrow vertical stake upon the ground at a given moment and calculating the azimuth of the sun at that moment. The sides of the packing box were lined up approximately with the meridian.

To assemble the parts of the spectrograph upon its mounting was the work of perhaps an hour. The lens and prisms had been put in place at Northfield and adjusted so as to give approximately angles of minimum deviation for the blue-green part of the spectrum, first with one prism and then with two, at the middle of the plate, and these positions were carefully marked on the bottom of the box so that the prisms could be replaced without repeating the adjustments.

On one of the afternoons preceding the day of the eclipse the sky was clear at the predicted time of totality, so that the polar axis could be brought into correct position, centering the blue of the spectrum on the plate. Then the packing box was loaded down with all the rocks it would hold and the post was stayed with braces so that the apparatus was quite rigid. Stays were driven into the ground so arranged that the piece of the camera box on which the plate-holder was to slide between exposures could be clamped to them at the time of totality, thus preventing much vibration when the plate was dropped from position to position for the successive exposures. It was not necessary to move the apparatus on the polar axis during the period of totality.

The greatest difficulty was encountered in focusing the apparatus. It was necessary to depend upon the sharpness, on the ground glass of the camera, of the edges of the continuous band of the solar spectrum, until just a few minutes before totality, when the narrowing cusps of disappearing sunlight began to give the effect of lines in the spectrum. Even then one could not be certain of the sharpness of the focus in the dark blue and violet, to which the eye is not very sensitive and for

which the lens was not fully corrected. As a result, the photographs are found to be slightly out of focus from the line Hδ on through the ultra-violet part of the spectrum. In this part, however, the scale of the spectrum is so much larger than that of the green and yellow portion, that the measures of the wave-lengths of the lines are even more accurate than where the lines are more sharply defined but the dispersion is smaller. On the other hand the number of lines photographed in the ultra-violet is smaller, partly because of the strong general absorption of the atmosphere and the glass prisms and lens in this region of the spectrum.

The Photographs.

On the day of the eclipse the sky was perfectly clear in the morning, but in the afternoon broken summer clouds formed and covered large portions of the sky. Fifteen minutes before totality a large clear space opened around and west of the sun. A black cloud, however, was approaching from the northwest, moving straight towards the sun and it seemed almost certain that the cloud would reach the sun before the moon's shadow reached us. I tested the focus as well as I could and made 5 exposures on the narrowing crescent of sunlight on one plate, stopping at 1 minute before the predicted time of beginning of totality. Changing the plate I waited with little hope for the signal of the moment of second contact, for the cloud was almost upon the sun. A sudden darkness came which I mentally attributed to the cloud, but it was really due to the advent of the moon's shadow, for at the same moment Mr. Darling, watching through a 4-inch telescope, called "time" for the moment of vanishing sunlight and our "totality program" was started.

An exposure of about one-half second duration was made instantly, i. e. as quickly as my brain and muscles could act. The position of the plate was changed and two exposures of 30 seconds each made, in different positions, during which I was able to look up and see the corona and prominences, and examine them with field glasses. A moment after "time" was called for the instant of reappearing sunlight an exposure of approximately a second was made. The plate-holder was changed and several very short exposures were made on the growing cusps of sunlight, during the first minute after totality. Then the cloud blotted out the sun for a half hour or more.

There must have been a thin film of cloud of varying density over at least parts of the sun during totality, for the shifting images of some of the prominences show gradations of brightness during the 30 seconds exposures, some which were being covered by the moon growing at first fainter, then brighter, then fainter, while others which were being

uncovered grew brighter and then fainter. The chromospheric half rings at H and K made a much stronger impression before being covered in the first part of the first 30 seconds exposure, than those which were uncovered during the last part of the second 30 seconds exposure.

The photographs of the cusps of sunlight before and after totality were too much overexposed to permit of profitable study, although they show some interesting features in the ultra-violet.

The two 30 seconds exposures during totality were also very much over-exposed and the drift of the image in 30 seconds prevents the possibility of accurate measurements of wave-length. Ten solar prominences are shown in the H and K regions during the whole of both exposures. The coronal ring at wave-length 5303 angstroms is shown in both and is nowhere perceptibly wider than the drift of the image in 30 seconds. The ring is therefore produced by a very limited depth of the corona, just above or in the upper layers of the chromosphere. It shows no trace at all of the prominences and so it is evident that the prominences do not contain much coronal matter.

The two exposures made just after second and third contacts yielded measurable spectra, quite sharp except in the ultra-violet. The former, which we will designate Exposure I, was too late for the "flash" and shows only chromospheric lines, 173 of which were measurable. The latter (Exposure II) appears to have been a little too late, but the irregularities of the moon's edge produced a fortunate result. A valley just at the point of last contact allowed just enough of the photosphere to project to produce a continuous spectrum, with no absorption lines, while the mountains on each side shut off the light from the photosphere and part of the reversing layer. Another valley, a little to the north of the first, allowed more of the light from the reversing layer to pass, with none from the photosphere. In this very narrow band of the spectrum there are many exceedingly short bright lines which we dared not include in the measures, lest they be simply accidental arrangements of the silver grains in straight lines. We have included 1037 lines in our final results.

The Plates and Extent of Spectrum.

The plates used were Seed's Nonhalation Ortho, which have two maxima of sensitiveness, one between $H\beta$ and $H\gamma$ and the other (shorter) between wave-lengths 5400 and 5700 angstroms. The measured length of the spectrum recorded in Exposure II is 143 mm, extending from wave-length λ 3798 ($H\theta$) in the ultra-violet to λ 5896 (Na) in the yellow. The strong line which we at first took to be the hydrogen line $H\alpha$ is the helium line D_3.

Measurement of the Plate.

The plate recording the two flash spectra was measured with a Gaertner measuring machine, one revolution of the micrometer screw of which is equal to one half millimeter. The screw head is three and one-half inches in diameter and is divided into 500 parts. In practice we read to the half of the smallest division or one two thousandth of a millimeter. The spectrum of Exposure I was measured in duplicate, both direct and reverse, by the writer and Mr. D. C. Kazarinoff, the measures agreeing generally within 0.010^r. Exposure II was measured direct and reverse by the writer.

Scale of the Plate.

The scale of the plate, since the spectrum was produced by two 60° prisms in series, varies greatly from the blue to the yellow end, being 5.4 angstroms per millimeter at λ 3798 Hθ and 39.4 angstroms per millimeter at λ 5876 D_3. The resulting wave-lengths are therefore far less accurate in the green portion than in the violet part of the spectrum, and consequently the identification of the lines from the measures is more difficult toward the green and yellow.

Reduction of the Measures.

The measures were reduced first by the use of the Hartmann formula

$$\lambda = \lambda_0 + \frac{c}{n - n_0},$$

in which n is the micrometer reading, λ the computed wave-length, and λ_0, c and n_0, are constants determined by means of the adopted wave-lengths of three or more known lines. Solving equations for three known lines we have

$$n_0 = \frac{(\lambda_2 - \lambda_1)(n_3 - n_1) n_2 - (\lambda_3 - \lambda_1)(n_2 - n_1) n_3}{(\lambda_2 - \lambda_1)(n_3 - n_1) - (\lambda_3 - \lambda_1)(n_2 - n_1)},$$

$$\lambda_0 = \frac{\lambda_3(\lambda_2 - \lambda_1)(n_3 - n_1) - \lambda_2(\lambda_3 - \lambda_1)(n_2 - n_1)}{(\lambda_2 - \lambda_1)(n_3 - n_1) - (\lambda_3 - \lambda_1)(n_2 - n_1)},$$

and

$$c = (\lambda_2 - \lambda_0)(n_2 - n_0).$$

As the Hartmann formula is not precise for such a long stretch of spectrum, it was necessary to determine two sets of constants, one for the violet and ultra violet region, and the other for the blue and green. Even this was not sufficient, so that finally the residuals were plotted for all the lines which could be reasonably well identified in Rowland's "Preliminary Table of Solar Spectrum Wave-Lengths" (*Astrophysical Journal*, Vols. I and II) and a smooth curve was drawn through the plotted points. The measured wave-lengths, as corrected by means of

this curve, are presented in Table I. The maximum correction obtained from the curve was 0.26 angstrom.

The reductions were performed mostly by the writer, aided in part by Mr. Kazarinoff. They were thoroughly checked by Mr. Kazarinoff through the use of a differential table, prepared by means of the formula

$$\Delta\lambda = -\frac{c}{(n-n_0)^2}\,\Delta n.$$

In most cases the results have checked within .01 or .02 angstrom.

EXPLANATION OF THE COLUMNS OF TABLE I.

In Table I the results of the measures of the spectra obtained in Exposures I and II are given side by side with the results obtained by S. A. Mitchell at the total eclipse of May 19, 1901, and the adopted standard wave-lengths of solar lines according to Rowland. The first and third columns give the writer's estimate of the intensity of the lines on a purely arbitrary scale, which is however fairly uniform throughout the length of the spectrum, 0 meaning that the line, though easily seen, was weak and difficult to measure, 1 that it was easily measured, 10 that it was very strong and almost too wide to measure. The strongest line is the hydrogen line H_γ, estimated on my scale as of intensity 20 in Exposure I and 40 in Exposure II. In column 3, the letter *c* before the numeral denotes that the line was regarded as chromospheric when the measures were made, judging from its appearance and length. The letters *d*, *t* and *w*, following the numerals signify that the line appeared *double*, *triple*, or *wide*, a question mark indicating uncertainty as to the character of the line; *r* signifies the observer's opinion at the time of measurement that the measure should probably be rejected. On a second examination of the plate most of the measures marked *r* were thrown out. A few were retained because on the second examination the lines seemed good enough to be recorded, but the record of the first opinion was allowed to stand. The braces connecting successive lines indicate that the lines were partly blended together.

Columns 5 and 6 give Mitchell's estimates of intensity and measured wave-lengths. His scale of intensity is from 1 to 3 steps below mine on the average, but the difference varies in different parts of the spectrum, and the discrepancy is greater in the case of the strong lines. It will be seen by comparison of the respective columns that we agree very closely in the resulting wave-lengths. Where we differ much the lines are usually double or blended with other lines.

Columns 7 and 8 give the intensity and wave-lengths in Rowland's "Preliminary Table of Solar Spectrum Wave-lengths" (*Astrophysical Journal*, Vols. I and II), of such dark lines as may possibly be identified with the bright lines of the "flash" spectrum as measured. In

many cases the identification is certain, in others it is impossible to decide between two or more solar lines. In a large number of instances the photographed line results from a blend of two or more solar lines and, where these are of unequal intensities, it is difficult to determine the wave-length of the "center of density" of the blend. On the whole, however, the agreement of the measured with the solar lines is very satisfactory.

In general it has been possible to find a solar line to represent every "flash" line. I have hesitated to use any of the lines with intensity marked 0, 00, or fainter, by Rowland, since there are ordinarily three or four of these within the limits of error of each measured line. Nearly all of the lines which have been left unidentified in Table I could have been represented by such faint solar lines but could hardly be said to be identified with them.

On the other hand, practically all the strong solar lines, those marked as of intensity 3 or more, which come within the limits of the well-defined parts of the photographed spectrum, find their counter-parts there, either in definite coincidence of wave-length or blended with other lines. In some parts of the photograph, especially in the green region, whole groups of lines were so run together and blended that it was impossible to measure any individual lines. I have gone over the plate with a list of missing solar lines of intensity 3 and 4 and find that none is certainly missing; all are represented in blends with, or hidden by the photographic irradiation from, other lines. Some were seen so plainly on the second examination that they could be measured if it were worth while.

The ninth column gives the identification according to Rowland of the substances producing the various lines in the spectrum. The following abbreviations are employed:

Ag	Silver	Fe	Iron	Sc	Scandium
Al	Aluminum	H	Hydrogen	Si	Silicon
Ba	Barium	He	Helium	Sr	Strontium
C	Carbon	La	Lanthanum	Ti	Titanium
Ca	Calcium	Mg	Magnesium	V	Vanadium
Ce	Cerium	Mn	Manganese	Y	Yttrium
Cd	Cadmium	Na	Sodium	Zn	Zinc
Co	Cobalt	Nd	Neodymium	Zr	Zirconium
Cr	Chromium	Ni	Nickel		

It will be seen from this list of abbreviations that probably 26 elements have been identified in the flash spectrum. Two of these, silver (Ag) and cadmium (Cd), are represented by only one line each and so should perhaps be regarded as uncertain. The silver line at $\lambda 4476$ has an iron line almost coincident with it and the measures probably represent both of them. The cadmium line at $\lambda 4678$ is partly blended with the iron line at $\lambda 4679$ but the measures give the wave-lengths of both quite accurately.

TABLE I.

Exposure I Chromosphere		Exposure II Flash		Mitchell 1901		Rowland Lines in Sun		Substance
Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	
		c 1	3798.11			...	(3798.1)	H (H*θ*)
		0	3832.46			15	3832.450	Mg
		c 3	3835.63	8	3835.2	...	(3835.54)	H (H*η*)
		c 1	3838.43			25	3838.435	Mg-C
				2*d*	3839.9	8	3840.580	Fe-C
		c 1	3878.74	2*d*	3878.4	8	3878.152	Fe-C
						7*Nd*?	3878.720	Fe
		c 1	3886.48			15	3886.434	Fe
		c 7	3889.10	8	3889.0	...	(3889.14)	H (H*ζ*)
		c 1	3890.98			3	3890.986	Fe
				0	3894.2	3	3894.165	Cr
						5	.241	Co
				0	3895.8	7	3895.803	Fe
		c 3	3900.61	2*d*?	3900.5	5	3900.681	Ti-Fe-Zr
				0	3902.3	3	3902.399	V
				0	3904.2	8	3904.023	
						2	3913.123	Ni
		c 3	3913.49	2*d*?	3913.3	5*d*?	.609	Ti-Fe
						4	.775	
						5*d*?	3915.951	Cr-
		c 1*w*	3916.17			2	16.383	Cr
				0	3917.5	4	3918.464	Fe
		0	3918.57	00	3919.1 group	4	.563	Fe
		0	3920.44			10	3920.410	Fe
				00	3922.3			
		0	3922.96			12*d*?	3923.054	Fe
		1*d*?	3928.05			8	3928.075	Fe
		1*w*	3930.44			8	3930.450	Fe
10	3933.76	*c* 15	3933.82	10	3933.8	1000	3933.825	Ca (K)
		1	3938.38			4	3938.552	
		* *c* 2*w*	3944.16	1	3944.6	15	3944.160	Al
		0*w*	3945.35			0	3945.358	
				0	3948.3	5	3948.246	Fe
		1*d*?	3948.85			4	.818	Ti
						4	.925	Fe
		1	3950.39			5	3950.102	Fe
		1	3952.14	0	3952.1	2	3952.103	Mn
		1*w*	3952.87			4	3952.754	Fe
						3	.850	Fe
						3	3953.043	Mn
						4	3956.476	Co-Ti
		1	3956.62			4	.603	Fe
						6	.819	Fe
		2	3958.27			5	3958.355	Ti, Zr
						4	3960.422	Fe
				0*t*	3961.3	3	61.281	Fe
		3	3961.64			20	61.674	Al

* Broad with three maxima.

TABLE I—Continued.

Exposure I Chromosphere		Exposure II Flash		Mitchell 1901		Rowland Lines in Sun		Substance
Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	
10	3968.53	*c* 15	3968.58	10	3969.0	700	3968.625	Ca (H)
5	3970.30	*c* 10	3970.27			5*N*	3970.177	H (Hε)
						4	3981.917	Ti
		2*t*	3982.48	1*t*	3982.5	2	3982.142	Fe?
						2	.630	Ti-Mn
						3	.742	Y
		0	3984.02			3	3984.059	Cr
						4	.113	Fe
						0	3988.659	La
		1	3988.76	0*d*?	3989.0	3	3989.137	
						2	.232	
		0	3989.77			4	3989.912	Ti
						3	3990.011	Fe
		1	3990.16			1	.129	Cr-Mn
		1	3991.30	0	3991.0	3	3991.333	Cr, Zr
		1*w*	3992.23			2	3992.396	
				1	3995.5			
		0	3997.32			1	3997.258	Cr?
						4	.547	Fe
		0	3998.05	1	3998.3	4	3998.053	Co
						4	.205	Fe
		3	3999.13			1	3999.117	Zr, Fe
		3*w*	4005.42	1*d*	4004.9	7	4005.408	Fe
				2	4006.0	3	4005.856	V
		0	4007.33			3	4007.429	Fe
				0*d*	4009.1	3	4009.079	Ti
		5*d*?	4012.52	1	4012.4	4	4012.541	Ti
		1	4014.72			5*d*?	4014.677	Fe
		* 0	4017.38			4	4017.308	Fe
		0*d*	4018.10	00	4018.1	3	4018.234	Mn
						4	.269	Mn
		0	4018.62			3	4018.420	Fe
		1	4019.10			1	4019.201	Ni-Ce
		2	4022.05	1	4021.9	5	4022.018	Fe
						2	4022.893	Fe
		1*w*	4023.46			3	23.533	Co-
						2	23.834	Sc
		2*t*	4025.14			0	4025.158	Cr
						3	.286	Ti-
						2	4025.972	Co-La
1	4026.52	*c* 3	4026.42	4	4026.0	...	(4026.342)	He
						2*N*	4026.583	Mn
		2	4028.49	0	4028.4	4	4028.497	Ti-
		0	4029.82			5	4029.796	Fe-Zr
						5	4030.646	Fe-Ti
						4	.878	Mn
0	4031.02	*c* 3	4030.92	1	4030.8	5	.947	Mn
						2	4031.048	

* Narrow maxima in blend of weak lines.

TABLE I—Continued.

Exposure I Chromosphere		Exposure II Flash		Mitchell 1901		Rowland Lines in Sun		Substance
Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	
		1	4031.94	0	4032.0	2	4031.942	Mn
		c 4	4033.24	1	4033.3	7*d*?	4033.224	Fe-Mn
		2	4034.65	1	4034.6	6*d*?	4034.644	Mn-Fe
		1	4035.81	0	4035.7	2	4035.752	Co
						4*d*?	.883	Mn
						3	4040.792	Fe
		2*d*	4041.14			3	4041.431	Fe
						5	.525	Mn
		1	4042.89					
1	4045.68							
1	4046.17	*c* 6	4045.94	2	4045.9	30	4045.975	Fe
				0	4047.8			
		2	4048.91	00	4048.9	5	4048.910	Mn-Cr
				0*d*?	4049.7	1*N*	4049.716	
		0*r*	4050.55			0	4050.482	Zr
		1*t*?	4053.96	0	4052.0	3	4053.981	Fe-Ti
		1	4054.97			2	4054.962	
		1	4055.37	0	4055.7	3	4055.023	Fe
						3	.189	Ti-Fe
						6	.701	Mn
		0*r*	4056.04					
						3	4057.499	Fe
		1	4057.58			7	.668	
*				00	4058.3	4	4058.372	Co-Fe
		1	4059.08			3	.915	Fe, Cr
						3	4059.081	Mn
		2	4061.30			3	4061.244	Nd-
		1	4062.98			5	4062.599	Fe Ragged
						4	4063.436	Fe
		c 3	4063.78	2	4063.5	20	4063.759	Fe
				1	4066.6	2	4066.524	Co
						2	.742	Fe
1	4067.57	*c* 2*w*	4067.26			5	4067.139	Fe
						3	.429	Fe
0	4068.56					0	4068.694	Co
				0	4069.3	2	4069.221	
1	4071.97	*c* 4	4071.92	2	4072.0	15	4071.908	Fe
		1	4073.76			4	4073.921	Fe
		0	4075.11			0	4075.055	Ni, Zr, Cr
		0	4076.14			3	4076.101	Fe
						4	4076.792	Fe
		0	4076.90			2	.959	Fe
5	4077.91	*c* 8	4077.88	6	4077.7	8	4077.885	Sr
		1	4083.55	00	4083.1	4	4083.095	Mn
						4	.783	Mn, Y
		1*w*	4085.36			4	4085.161	Fe
					group	4	.467	Fe
		2	4086.58			3*d*?	4086.469	Co-
		2	4086.93			1	4086.861	La
				00	4087.2	3	4087.252	Fe

* Faint line between these.

TABLE I—Continued.

Exposure I Chromosphere		Exposure II Flash		Mitchell 1901		Rowland Lines in Sun		Substance
Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	
		2	4092.46			2	4092.431	Fe
						3	.547	Co, Mn
		2	4092.80			3*d*?	4092.821	V, Ca?
		1	4096.11			3	4096.129	Fe
						2	.262	Fe
		0	4096.55					Narrow
						3	4097.241	Fe
		2	4098.38			5	4098.335	Fe
15	4101.81	*c* 15	4101.83	10	4102.0	40*N*	4102.000	H, In (Hδ)
		1	4103.07			5	4103.097	Si, Mn
		0	4104.31			5	4104.288	Fe Narrow
		0*d*	4105.26			2	4105.318	V "
		1*r*	4106.54			2	4106.420	Fe Crooked
						2	.583	Fe
		2	4107.66	0	4107.7	5	4107.649	Ce-Fe-Zr
		1	4109.39			3	4109.215	Fe
				0*t*	4109.5	1	.609	Nd?
						2	.905	V
		2	4109.89			3	.953	Fe
		1	4110.74			4	4110.691	Co
		1	4111.96			4	4111.944	V
		1	4114.61			4	4114.606	Fe
						2	4115.094	
		1	4115.34			3	.330	V
		†0	4116.48			1	4116.634	V
		1	4116.83			1	4116.859	Nd?
		4*d*	4118.84	0	4118.7	5	4118.708	Fe
						4	.934	Co
		0	4120.60			4	4120.368	Fe
		3*d*	4121.47	0	4121.4	6*d*?	4121.477	Cr-Co
		3	4122.75			3	4122.673	Fe
				0	4123.2	1	.819	
		3	4123.73			12	4123.384	La Wide
						1	.664	Mn
		1	4124.04			5	.907	Fe Narrow
		1*w*	4125.02					
						3	4126.040	Fe
		1*w*	4126.24			4	.344	Fe
						4	4127.767	Fe
		4*t*?	4127.91	0	4127.7	4	.957	Fe
						6*d*	4128.251	V
						3	4129.337	Ce-
		4*w*	4129.80			1	.881	
						2	4130.196	Fe
		1	4130.64			0	4130.604	
					Group	2	.804	Ba
		1	4131.11			0*Nd*?	4131.013	
						1	.271	Mn

* Group of several lines.

† Pair of narrow lines.

TABLE I—Continued.

Exposure I Chromosphere		Exposure II Flash		Mitchell 1901		Rowland Lines in Sun		Substance
Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	
		1	4131.83					
		3	4132.21			10	4132.235	Fe
		1	4132.97			4	4133.062	Fe
						0	4133.965	Ce
		0*d*?	4133.96			3	34.010	Fe
						3	4134.492	Fe?
		2	4134.59			3	.589	V-Fe?
		2	4134.87	0	4134.8	5	4134.840	Fe
		0	4135.61			0*Nd*?	4135.610	
		* 1	4137.12			6	4137.156	Fe
				1*d*	4137.3	2	.567	
		1	4137.85			1	.809	Fe, Ce
				0*d*	4140.3			
				0	4142.0	4	4142.025	Fe
		1	4142.70			2	4142.629	Cr
						2	.744	
		2	4143.17			4	4143.572	Fe
1	4143.75	*c*				...	(4143.919)	He
1	4144.11	3	4144.07	2*d*?	4144.0	15	4144.038	Fe
		1*d*?	4146.30	0	4146.3	3	4146.225	Fe
		0	4147.50			2	4147.502	
						1	.645	Mn
		1	4147.85	00	4147.9	4	4147.836	Fe
						0	4149.285	C
		c 4	4149.32	1*d*	4149.3	2	.360	Zr
						4	.533	Fe
		1	4149.94	0	4149.9	2	4149.923	
		1	4151.20			1	4151.129	Zr, Ti
		c 3	4152.21	00	4152.3	2	4152.108	Fe, La
						3	.343	Fe
		1*w*	4153.90	1	4154.1	1	4153.971	Cr
						4	4154.071	Fe
		2*w*	4154.77			4	4154.667	Fe
						4	.976	Fe
		c 4	4156.34	1	4156.2	1	4156.391	Zr
				0	4156.4	3	.471	
		1	4157.01	0	4157.5	3*d*?	.970	Fe
		1*d*	4158.03			5	4157.948	Fe
		1	4159.08			5	4158.959	Fe
		1	4159.48			5	4159.353	
		0	4160.30			0	4160.256	
		1	4160.94			0	4160.942	
		c 3*d*?	4161.54	0	4161.7	4	4161.682	Ti
		0	4162.36					
		0	4162.99					
		2	4163.60					
1	4163.90	*c* 3	4163.98	1	4163.8	4	4163.818	Ti, Cr-
		1	4164.56			0	4164.493	
		1	4165.55			3*d*	4165.550	Fe Ragged

* Several lines partly blended.

TABLE I—Continued.

Exposure I Chromosphere		Exposure II Flash		Mitchell 1901		Rowland Lines in Sun		Substance
Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	
						0	4167.126	Ce
		2	4167.34	1	4167.0	8	.438	Ca?
						1*Nd*?	.737	
		2	4167.73	1	4167.9	1*N*	4167.884	C
		1	4169.90			2	4169.926	
		0	4170.90			4	4171.068	Fe
		0*r*	4171.44			4	.213	Ti,-
				2	4171.6	2	4171.854	Cr, La, Mn, Ni, Fe
0	4172.19	*c* 4	4172.14			2	4172.066	Ti, Fe
				1	4172.4	2	.296	Fe
		0	4172.82			4	4172.923	Fe
1	4173.62	*c* 5	4173.60	1	4173.6	3	4173.624	
						3	.710	Ti
				0	4175.3	4	4175.082	Fe
		1	4175.88	0	4175.8	5	4175.806	Fe
		0	4176.66	0	4176.5	5	4176.739	Fe-Mn
1	4177.66	*c* 6	4177.71	1	4177.3	3	4177.698	Fe
						3	.772	
		3	4178.77		group	2	4178.223	
0	4179.11	*c* 3	4179.14	1	4179.1	3	4179.025	Fe
		1	4179.62			3	4179.542	V,-
		• 1	4180.75	0*d*?	4180.3	1	4180.563	
						2*N*	.970	C
		• 1	4181.18					
		1	4181.85	5	4181.8	5	4181.919	Fe
		2	4182.05					
		1	4184.45	0	4184.4	2	4184.472	Ti Ragged
		2	4185.26			4	4185.058	Fe, Cr "
		0*r*	4186.39	00	4186.2	1	4186.280	Ti
		3	4186.96			2*N*	4186.778	Ce-Zr
				0	4187.2	6	4187.204	Fe
		3	4187.55			2	4187.747	Fe
				0	4187.9	5	4187.943	Fe
		3	4188.10			3	4188.019	
		0	4188.99	0	4188.9	4	4188.894	
		0*r*	4189.58			2	4189.723	C,-
		0*r*	4190.16			0*N*	4190.147	Mn
		4*w*	4191.65	0*d*	4191.7	6	4191.595	Fe
						3	.843	Fe
		• 1	4193.19	0	4193.0			
		0	4193.59					
		† 1	4194.15	0	4194.0			
		0*r*	4194.58					
		1	4194.98			1	4195.006	Cr
		2	4195.53	0	4195.3	5	4195.492	Fe

• Very narrow.

† Edge of faint band.

TABLE I—Continued.

Exposure I Chromosphere		Exposure II Flash		Mitchell 1901		Rowland Lines in Sun		Substance	
Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length		
		2	4196.44			4	4196.372	Fe	Ragged
						2	.699	La	
		2	4196.89			1	4196.837	Fe	"
		1	4197.27			2	4197.257	C	"
		2	4198.23			2	4198.221	Fe	
						4	4198.402		
		3	4198.51	1	4198.6	4	.494	Fe	
		1	4198.87			3	4198.800	Fe	
		3	4199.28	1	4199.2	5	4199.267	Zr-Fe	
		0*d*?	4200.23			2	4200.148	Fe	
				00*t*	4200.8	1	4200.761		
						1	.946	Ti	
		1	4201.07			3	4201.089	Fe	Ragged
1	4202.22	*c 2	4202.14	1	4202.2	8	4202.198	Fe	
		1	4202.40			0*N*d?	4202.514		
		† 0	4203.11			0*N*	4203.100		
		1	4204.05	00	4204.0	3	4204.101	Fe	Narrow
						4	.163	La	
		1	4204.87	00	4204.9	2	4204.916		
		2	4205.23			1	4205.186		
						1	.239		
		1	4205.53	0	4205.5	1*N*	4205.545	Fe	
				00	4206.1	2	4205.702		
		‡ 2	4206.93	0	4206.8	3	4206.862	Fe	
				0	4207.7	3	4207.291	Fe	
		0	4208.42	0	4208.6	0	4208 514	Cr	
						3	.766	Fe	
		3	4209.10	0	4209.1	1	4209.144	Zr	
		0	4209.57			0	4209.521	C	
						1	4209.660	V	
		0*r*	4210.15	0	4209.9	0	4209.985	Cr	
		2*w*	4210.62	0	4210.5	4	4210.494	Fe	
						3	.565		
		¶ 0*r*	4211.33	0	4211.3	3*N*	4211.127	C-Cr	
						0*N*	·512		
		1*d*	4212.12	00	4212.0	2	4212.048	Zr-	
		0*r*	4212.91	00	4212.8	3*N*	4212.801	Cr?	
		0	4213.49			0*N*	4213.323	C, Cr	
		1	4213.85	00	4213.7	3	4213.812	Fe	
		0	4214.29						
						2	4215.581	Fe	
5	4215.68	*c* 10	4215.64	8	4215.7	5*d*?	4215.703	Sr	
		1	4217.37			1	4217.365		
						1	.420		
		1	4217.71	0*d*?	4217.8	5*d*?	4217.720	La, Fe-Cr	

* Single in chromosphere, double in sun.

† Very narrow.

‡ Ragged narrow line on each side.

¶ Possibly middle of two.

TABLE I—Continued.

Exposure I Chromosphere		Exposure II Flash		Mitchell 1901		Rowland Lines in Sun		Substance
Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	Intensity	Wave-Length	
		0*r*	4218.40			1	4218.384	
						1*Nd*	.558	-Zr
		0*r*	4218.77			3*N*	4218.885	
		2	4219.55	00	4219.5	4	4219.516	Fe
						3	.580	
		0	4220.31	0*d*?	4220.3	1	4220.212	
		1	4220.51			3	4220.509	Fe
		0	4222.01					
		2	4222.57	0*d*?	4222.7	5	4222.382	Fe
		1	4223.12	0	4223.4	1*N*	4223.256	
		0*r*	4223.75			1	4223.738	
		1	4224.26	0	4224.5	4	4224.337	Fe
		1	4224.78			3	4224.673	Cr-Fe
		2	4225.47	0*d*	4225.6	3	4225.619	Fe
		1	4225.85			1	4225.874	
3	4226.91	*c* 6	4226.86	3	4226.9	20*d*?	4226.904	Ca
		1	4227.62			4	4227.606	Fe
		1	4229.93			3	4229.926	Fe
		0	4230.29					
		0	4231.28	0	4231.1	4*N*	4231.183	Ni
		0	4232.43					
						2	4232.887	Fe
2	4233.34	*c* 5	4233.32	3	4233.2	4	4233.328	Mn-Fe
						6	.772	Fe
		1	4235.33	0	4235.4	2	4235.298	Mn
						3	.450	Mn
0	4236.18	*c* 3*d*?	4236.05	2	4235.8	8	4236.112	Fe
		1	4237.10			1	4237.240	
				00	4237.2	3	.339	Fe
		1	4237.49			1	.412	
		1	4238.05	1	4238.0	3	4238.188	Fe
		1	4238.36					
		2	4238.86			5	4238.970	Fe
		1	4239.19			2	4239.525	
						3	4239.890	Mn
		2*w*	4239.99	1*d*?	4239.9	3	4240.014	Fe
						2	4242.535	
		2*d*	4242.69			2	.615	
						2	.760	
						2	.897	Fe
		0	4243.23	1*d*?	4243.1	1*d*?	4243.364	
						3	4243.608	Fe
		1	4243.81			1	.714	
						2	.981	
		1	4245.53			4	4245.422	Fe
						2	.520	
		0	4246.20			2	4246.251	Fe
4	4246.90	*c* 7	4246.95	4	4247.0	5	4246.996	Y?
		1	4247.74			4	4247.591	Fe

(To be Continued.)

MONISTIC AND DUALISTIC CONCEPTIONS OF THE STELLAR UNIVERSE.*

C. V. L. CHARLIER.

1. The last ten years have brought about the gradual development of two diametrically opposed ideas in regard to our stellar universe—ideas which may be fitly characterized by the distinction implied in the title of this article. According to the monistic conception, the stellar universe is thought of as a single system, which, if not really in equilibrium, is well on the road to such a state. Others maintain that the stellar system can be better explained as a mixture of two systems, which are in the process of blending, the one with the other, and giving birth to a stellar universe which is far from being in what we should call in mechanics a stable state of distribution. It is asserted by both sides that they have established their opinions upon facts; and, in truth, the interpretation of the latter is so intricate that we are able, in many instances, (to use them) to support first one and then the other hypothesis.

For Herschel and the astronomers of the last century the monistic point of view was the natural point of view. It was only when Kapteyn in 1904 set forth his celebrated theory of two star streams, that we seriously doubted the monistic conception of the stellar universe and demanded if it was adequate. In truth this hypothesis of Kapteyn seemed to explain in a simple way the anomalies in the proper motions of the stars to which Kobold some years before had directed the attention of astronomers. However, only three years after that, we find Schwartzschild showing that the same phenomena might be explained without giving up the monistic conception. He, nevertheless, was unable to prove that his hypothesis was superior to that of Kapteyn.

Since then each new discovery in stellar astronomy—and there have been many recently, especially in the field of stellar spectroscopy—has been discussed from the point of view of one or the other of the two hypotheses.

It is justifiable first to say that the monistic conception has been recently revived and its foundations strengthened by the relation which has been established between the motions of stars and the kinetic

* Translated by Miss Evelyn W. Wickham, of the Yerkes Observatory, from an article by C. V. L. Charlier in *Scientia* 1917.

theory of gases which has been developed by Clausius and Maxwell This analogy was first suggested by Sir William Thomson (Lord Kelvin). But Poincaré (in his *Hypothéses cosmogoniques*, 1911) was the first to really try to apply the kinetic theory to the stars. He was not concerned there, however, with the fundamental problem in connection with the kinetic theory—in knowing the frequency of the distribution of stellar velocities. The problem has been approached more recently by Halm and Jeans and the writer, who has furthermore made great use of the kinetic theory in the lectures which he has given at Lund during the last two years.

The main idea in the kinetic theory is the following: Consider a group of stars made up of a great number—some millions of single ones. The motion of one individual star is governed by the attraction of the others according to Newton's law. It is evidently impossible to consider *exactly* the attraction of each of the stars, partly because the work would be overwhelming on account of the calculation, and partly because we never know, and never will be able to know, with sufficient precision the relative position and the velocity of the stars. Therefore, we approach the problem in another way. The attraction of each individual star depends apparently, for the most part, upon the attraction of the *whole* of the group. The distances between the stars are great, and the orbit of an individual is, at least for a long time, the same as that of a particle moving in a field of force having at all points the same potential as the entire group. If the density of distribution of the stars and of the distribution of velocities at each point of the group remains unaltered, the system may be said to be in *dynamical* equilibrium. If this equilibrium does not exist, the density of distribution varies from time to time.

Even in the case of very diffuse groups of stars we cannot be sure that the star under consideration will not pass from time to time, though perhaps at very long intervals, very near to another star so that its orbit will be suddenly and completely changed. Since the influence of these passages—in the kinetic theory of gases they are called collisions —cannot be analyzed by means of ordinary mechanics, we study it by the theory of probabilities. The result is the kinetic theory, known also as "statistical mechanics". This theory shows that the passages, in the course of time, smooth out the differences in the velocities of the stars, until at last an equilibrium—a *statistical* equilibrium—may be reached. The velocities in each part of the group are then distributed according to Maxwell's law.

Another important question is that connected with the mixture of stars of different masses. Here an *equipartition of energy* is produced, such that the product of the mass of a star by the square of its velocity

is, on the average, the same for stars of all sizes. Thus, in the long run, the most massive stars have the smallest, while the smallest ones acquire the greatest mean velocities.

Let us pass now from the kinetic theory to the comparison of the monistic and dualistic theories of the universe. In the following table I have collected the principal problems which the two theories have tried to explain and have added a short description of the solution.

Problem.	Monistic theory.	Dualistic Theory.
1. *State of motion.*	The universe is almost in *dynamical* equilibrium and is constantly approaching *statistical* equilibrium.	Neither dynamical nor statistical equilibrium.
2. *Distribution of velocities of Stars.*	Generalized ellipsoidal theory resulting from the kinetic theory.	Two (perhaps more) star streams.
3. *Form of the Milky Way.*	(Ellipsoid of revolution.)	Spiral or irregular.
4. *Speed and spectral type.*	The mean speed depends upon the *masses* of the stars (mv^2 constant)	The speed increases with the *age* of the stars.
5. *Development of a star.*	(meteoric dust) red, yellow, white, yellow, red stars, (M. K. G. F. A. B. A. F. G. K. M.)	(nebulous gas) white yellow, red stars, (B. A. F. G. K. M.

The discussion of the five problems of the preceding table would be too long for an article in this journal, so I shall limit myself to the first one. In a general way I will give all the arguments in favor of the kinetic theory, and discuss the objections which have been made to its application to the stellar universe. The most important of these have been made by Jeans, Eddington and Poincaré, and I will discuss them here in their order.

2. *Jean's Objection*: The stellar universe may be in statistical equilibrium, and, in that case, also in dynamical equilibrium; or it may be only in dynamical equilibrium, or, according to the dualistic theory, it need be in neither dynamical nor statistical equilibrium. It is evident from the proper motions of the stars that it is not in statistical equilibrium. We shall see later, nevertheless, that it is manifestly approaching that state. In regard to the two other possibilities, the question was studied in 1915 by Jeans. The result of his researches was that "star streams, such as we have observed in the universe, do not seem to be in accord with the supposition, that our universe is in a stable state." Accepting the dualistic theory, I examined the problem at the same time as Jeans, in my lectures in 1915, and arrived at the opposite conclusion. To be more precise, I obtained the same mathe-

matical (and mechanical) result as Jeans, but we differ in regard to the application to the astronomical problem. As far as I can see, this is the explanation. For a stable state it is necessary—as a mathematical analysis shows—for the ellipsoid of velocity to be a spheroid whose axis of revolution is perpendicular to the radius vector drawn from the center of the universe. The observations show, in fact, that the surface of velocity is approximately an ellipsoid of revolution. What is the angle between the axis of revolution, and the radius vector from the center? We may have different opinions upon this point, in consequence of the difficulty which exists in determining the position of the center. Mr. Jeans thinks that this axis is directed towards the center (agreeing with Turner) while according to my opinion it is *approximately* (but not exactly) perpendicular to the radius vector as the theory demands. Since my determination of the center of the universe, from the distribution of helium stars (June 1916) was not known to Mr. Jeans at the date of the publication of his article (December 1915), I hope that he will find some reasons to modify his conclusions upon this point.

3. Let us now see to what extent we can accept the hypothesis that the universe is really on the road to a state of statistical equilibrium. This question has also been dealt with by Jeans, who, as the author of *La théorie dynamique des gaz*—the best treatise on the kinetic theory known to the author—is a peculiarly competent authority upon the subject. In order to measure the velocity with which a disturbed gas reaches a stable state, Maxwell made use of a quantity which he called the "relaxation time." The greater this time, the slower is the restoration to the stable state by the collisions of particles. It should be noted that the time necessary to establish (approximately) a statistical equilibrium is always greater than the "relaxation time", but one may consider the two times as being of the same order of magnitude. For gases, the time is of the order of 10^{-10} seconds. For stars, Jeans found the enormous value of 10^{14} years. Applying Newton's law to the problem (instead of Maxwell's law of repulsion, which Jeans used) I found the value 10^{16} years for the same quantity—a value of the same order of magnitude as Jeans. In other words, this shows that it would take the stellar universe some billions of years to arrive at statistical equilibrium by the collisions of stars. Jeans thinks this time too long "even for astronomy", and concludes that "there can be no question of a universe similar to ours arriving at a final stable state, like that with which the theory of gases has made us acquainted." Without doubt the period is very long and exceeds all our previous ideas as to the age of the stars. But have these ideas a foundation of sufficient accuracy? Have we taken scrupulous account of the phe-

nomena of radiation? I think not. In any case, it may be wise to examine the facts showing the influence of these collisions of stars upon the distribution of their velocities.

4. And indeed, facts of this kind are not lacking. In the following table, from Gyllenberg, are given the semi-axis of the ellipsoids of velocity.

SEMI-AXES OF THE ELLIPSOIDS OF VELOCITY OF STARS OF DIFFERENT SPECTRAL TYPE.

Color	Type	a_1	a_2	a_3	Ω
White stars	B & A	1.73	3.10	2.73	4.48
Yellow "	F & G	3.02	4.95	3.67	6.86
Red "	K & M	4.00	4.51	4.27	7.39

The figures represent siriometers per stellar year, the siriometer being equal to 10^6 astronomical units, and the stellar year being equal to 10^6 years. The axis a_1 is (approximately) directed to the center of the Milky Way; the axis a_2 is perpendicular to it in the Milky Way (toward the Vertex), and the axis a_3 is directed toward the pole of the Milky Way. Various researches made by Ludendorff, Shapley and others point to the conclusion that it is probable that the white stars have the greatest mass; next come the yellow, and the red ones have the smallest mass. Considering all these points we find:

1. The mean velocities (Ω) of the stars are proportionally greater as the masses of the stars are small, which agrees with the law of equipartition of energy in the kinetic theory.

2. The largest axis a_2 is approximately perpendicular to the radius vector drawn from the center.

3. The other axes (a_1 and a_3) are, at least for the yellow and red stars, almost of equal length, so that the ellipsoid of velocity is a spheroid, located (almost) in the position necessary for dynamical equilibrium.

4. For the smallest stars (red) the three axes of the ellipsoid of velocity are almost of the same length, showing that these stars are already, at least approximately, in statistical equilibrium.

This seems to show that the "relaxation time" in a group of stars is proportional to the mass of the latter.

These considerations are, indeed, purely provisional, for a separation of spectral types here taken together (B & A, F & G, etc.), is necessary before one can undertake a conclusive discussion. (Thus the ellipsoids of velocity of B type stars differ essentially from those of A type stars.) In any case, the preceding considerations seem to indicate that the "relaxation time", long as it may be, has already left some recognizable traces in the history of our stellar universe.

5. *Eddington's Objections*: Mr. Eddington, to whom we owe the most penetrating researches upon the subject of the two supposed star

streams, gives in his book *Stellar Movements and the Structure of the Universe* a complete criticism of the kinetic theory as applied to the stellar universe. This is his most direct argument. There are in the sky many systems of stars, traveling together in parallel orbits. Some show a great separation in space: for example the well known system of Ursa Major, composed of the five stars of The Plough (β, γ, δ, ϵ, ζ) and of ten others scattered over a large part of the sky, the most interesting being Sirius.

Certain of these systems have existed perhaps for a time comparable in length with the life of an average star. "They are traveling across a part of space where are scattered stars not belonging to their system. Nevertheless the equality of motion has not been seriously affected. It is scarcely possible not to conclude that the attractions due to accidental encounters of stars, in the neighborhood, have had no appreciable effect upon the stars' motion." Reasoning in this way, he concludes that "the apparent analogy with the kinetic theory is entirely out of the question," and that "the stars follow their paths under the influences of the general attraction of the stellar system without influencing one another."

One may say in reply to this argument that the stars which now belong to such a system are only the insignificant remains of a large cluster once constituting a very close system in space. Perhaps the stream of Ursa Major, consisting really of about a dozen stars, was made up, some millions or thousand millions of years ago, of a mass of millions of stars, of which the great majority have been scattered in all possible directions, due to the chance attractions of stars passing by in the neighborhood, leaving the most brilliant stars of The Plough as a very poor reminder of its ancient wealth. Is not the relative rarity of stars in such systems indirect proof that the very great number of stars in the original mass have succumbed by the way to collisions with other stars, which encounters, though certainly rare and insignificant, yet in the course of time are capable of scattering the members of the same family of stars in all directions, just as surely as *gutta cavat lapidem non vi sed saepe cadendo?* If it were not a question of saying too much upon the subject, one might be tempted to offer as another proof of the action of these collisions, the fact that the stars belonging to these groups are generally white stars, or, at least, large stars while the influence of collisions is felt most strongly in the case of the smallest stars, as we have seen in discussing the ellipsoid of velocity.

6. When one regards them in another light, the phenomena of systems of stars furnish another proof of the validity of the kinetic theory. Considering a group of stars—at first a globular cluster moving

out into space, more or less filled with stars at rest or moving in parallel courses. The members of the cluster have from time to time to pass very near other stars, and each time they have to undergo a certain deviation and change of velocity. Is the nature of the cluster *systematically* changed by these encounters, and if that be the case, what form will the moving system take? Jeans studied this problem in 1916 and concluded that the members of the moving system, at first distributed spherically, will at length spread out in the form of a disc which will continue to spread as time goes on. The plane of the disc will be perpendicular to the line in which the cluster moves.

The conditions for the application of Jeans' results are not actually realized in the universe. The motion of a cluster is not rectilinear, nor of the stars either. We may suppose that the cluster is describing an elliptical orbit about the center of the universe in a period estimated as some thousands of stellar years. One can scarcely expect that, in the orbital motion of the axis of the disc, into which the globular cluster is eventually changed, will remain parallel to the direction of motion; no more have we the right to consider that the ultimate form of the mass will be a disc. It is probable, not to push the analysis further, however, that the cluster will take the spheroidal form. It is quite remarkable that the only moving system which has at present been examined, shows this form.

Turner has shown that the system of Ursa Major has the form of a flat disc with diameter about eight siriometers and depth only about a half siriometer. We may, even if we do not have to, conclude that this cluster has had a lifetime equal to or greater than the "relaxation time", and that these encounters with other stars have, during the millions of revolutions about the center of the Milky Way, transformed the original more or less condensed cluster into the thin flattened disc which we now see, while the principal part has been scattered into different parts of the universe.

7. *Poincaré's Objection*:—We still have to consider one objection to the kinetic theory—an objection made by Poincaré in the article mentioned above. We have seen that one of the most important consequences of the kinetic theory is the law called the *equipartition of energy*, according to which the product of the mass by the square of the velocity is a constant for all kinds of bodies in the universe. A direct consequence of this law is that the ultimate velocity of small bodies must be very great and infinitely great in the case of bodies whose mass is evanescent. The comets furnish some examples of such masses, and according to the kinetic theory we ought to expect their velocities to be infinitely great. But we know that the velocities of comets and of stars are of the same order. How do we explain this

contradiction? Poincaré proposes to remove the difficulty by supposing that our system has not yet reached a stable state, which supposes that the comets have not yet attained their greatest velocities. The hypothesis upon which this rests—the hypothesis that any differentiation between the velocities of bodies of such different masses as comets and stars is not produced in the lifetime of our stellar universe—is evidently unsatisfactory and is in direct contradiction to the conclusion that the smaller stars, which have masses certainly millions of times greater than those of comets, have almost reached a stable state.

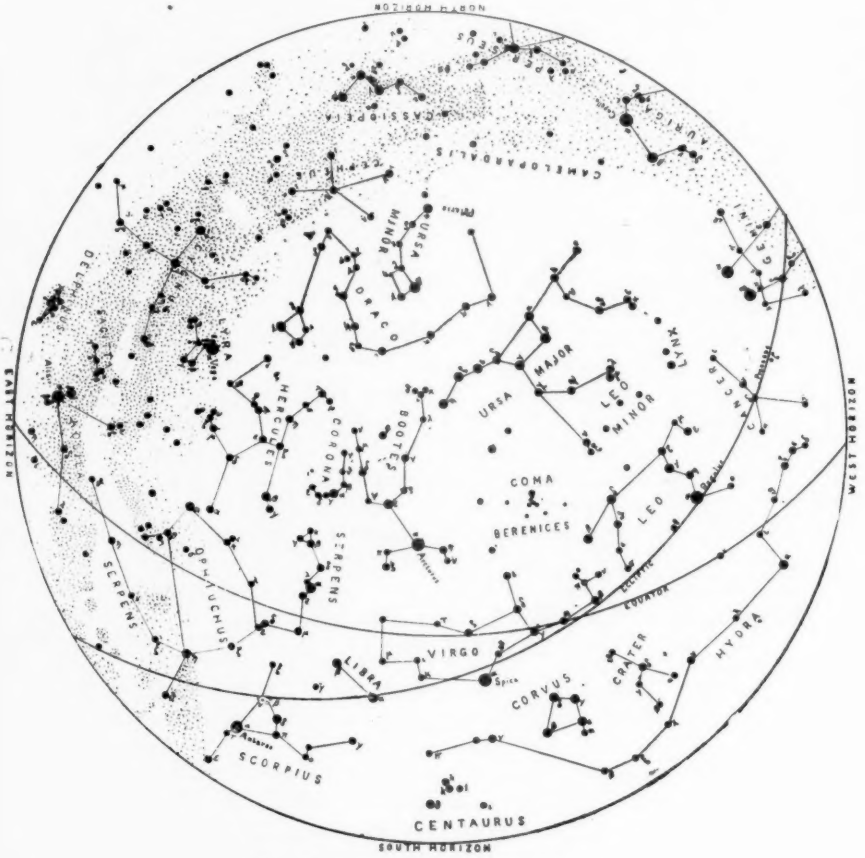
But there is another explanation which at the same time helps to settle an old and important cosmological question. According to the kinetic theory the comets ought to acquire, and have already acquired, very great or even infinite speeds. Why do we not observe comets of this kind? *We do not observe them because long ago they were expelled from the universe*—just as the lightest gases have been expelled from the atmosphere of some of the planets. The only ones which have escaped this are the ones captured by stars. All comets which we can see must be members of the solar system, describing elliptical orbits about the sun. Such, indeed, is the direct consequence of the kinetic theory.

We may go farther. The comets are not the only bodies in the universe which are small (infinitely small). There are the meteors and the particles of meteoric dust. These must also in time—time already past perhaps—either be expelled from the universe forever, or be captured by suns and their planetary systems. It is here perhaps that we need to look for the explanation of the singular fact that extinction of light in space does not exist or is vanishing small. The ultimate state of our stellar system then is an assembly of stars moving according to Maxwell's law in a space free from comets, dust and other infinitesimal particles, which have all been concentrated about these suns, if they have not been absorbed by them or their planets.

Lund Astronomical Observatory,
Sweden.

PLANET NOTES FOR JUNE, 1919.

The *sun* will reach its maximum northern declination for the year on June 22. This therefore will be the longest day for the northern hemisphere. By the end of



THE CONSTELLATIONS AT 9:00 P. M. JUNE 1.

the month the sun will have moved only about a quarter of a degree southward from its farthest position north. It will move from the constellation Taurus into the constellation Gemini.

The phases of the *moon* for this month are as follows.

First Quarter	June	5	at	6	A.M. C.S.T.
Full Moon		13	"	10	A.M. "
Last Quarter		20	"	12	P.M. "
New Moon		27	"	3	P.M. "

The summer time clock reading will be one hour greater for these phases.

The *moon* will be nearest the earth on June 25 and farthest from the earth on July 7.

Mercury will be moving eastward toward the sun at the beginning of the month and will pass the sun on the opposite side from the earth on June 11. By the end of the month it will be approaching a position of greatest elongation east It will set more than an hour after the sun, and will be visible on the western horizon in the evening.

Venus throughout the month will be more than three hours east of the sun and will therefore be visible until nearly midnight. It will continue to approach the earth and to become brighter during the month.

Mars will just be reappearing after the conjunction with the sun on May 9. At the end of the month it will rise about one hour before the sun and very near the same point on the horizon. It will therefore not be possible to observe this planet during June.

Jupiter will be moving eastward but much more slowly than the sun. It will therefore be sinking lower in the west from day to day at sunset, and will practically be out of reach for important observations. It will be receding from the earth. At the end of the month it will set about one hour after sunset.

Saturn will be visible in the west in the evening. At the beginning of the month it may still be easily observed. It will be several degrees farther south than the sun during this month.

Uranus will move through a diurnal arc which will cross the meridian at latitude 45° north about 35° above the horizon. It will therefore require very good conditions for northern observers to study this planet during this month.

Neptune in the early part of the month may be observed in the evening sky. By the end of the month the sun will have reached a position two hours west of this planet.

Occultations Visible at Washington.

[From the *American Ephemeris.*]

Date 1919	Star's Name	Magnitude	IMMERSION. Washington M.T.	IMMERSION. Angle from N.	EMERSION. Washington M.T.	EMERSION. Angle from N.	Duration
			h m	°	h m	°	h
June 2	60 Cancri	5.7	8 56	70	9 39	336	0 43
15	267 B Sagittarii	5.8	8 52	48	9 47	298	0 55
16	27 G Capricorni	6.2	10 16	87	11 26	244	1 10
23	π Arietis	5.2	15 06	57	16 01	265	0 54
29	84 B Cancri	6.4	8 38	83	9 22	315	0 45

Saturn's Satellites.

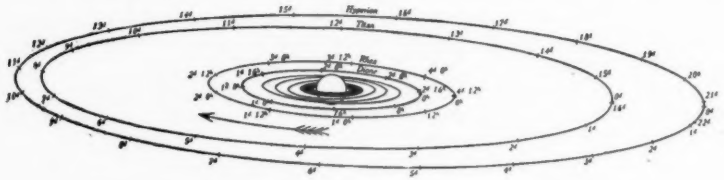
[From the *American Ephemeris.*]

CENTRAL STANDARD TIME.

I. Mimas. Period $0^d\ 22^h.6$.

1919	h		h		h		h	
June 1	7.2 W	June 8	8.9 E	June 14	12.0 W	June 16	9.2 W
6	11.7 E	9	7.6 E	15	10.6 W	17	7.8 W
7	10.3 E						

South



North

SATELLITES OF SATURN, 1919

Apparent Orbits of the Seven Inner Satellites of Saturn at Date of Opposition, February 14, 1919, as seen in an inverting telescope.

II. Enceladus. Period $1^d\ 8^h.9$.

June 2	5.7 E	June 7	17.2 E	June 13	4.8 E	June 17	7.5 E
3	14.6 E	9	2.1 E	14	13.7 E	18	16.4 E
4	23.4 E	10	11.0 E	15	22.6 E	20	1.3 E
6	8.3 E	11	19.9 E				

III. Tethys. Period $1^d\ 21^h.3$.

June 1	15.9 E	June 7	7.9 E	June 12	23.8 E	June 18	15.8 E
3	13.2 E	9	5.2 E	14	21.2 E	20	13.2 E
5	10.5 E	11	2.5 E	16	18.5 E		

IV. Dione. Period $2^d\ 17^h.7$.

June 1	11.7 E	June 9	16.9 E	June 15	4.4 E	June 20	16.8 E
4	5.5 E	12	10.6 E	17	22.1 E	23	9.5 E
6	23.2 E						

V. Rhea. Period $4^d\ 12^h.5$.

June 3	23.2 E	June 8	11.8 E	June 13	0.4 E	June 17	12.9 E

VI. Titan. Period $15^d\ 23^h.3$.

June 4	1.5 E	June 11	19.6 W	June 20	1.4 E

VII. Hyperion. Period $21^d\ 7^h.6$.

June 8	15.6 W	June 19	10.0 E

VIII. Iapetus. Period $79^d\ 22^h.1$.

June 7	9.6 E

IX. Phoebe. Period $523^d\ 15^h.6$.

	α Ph.—α Sat.	δ Ph.—δ Sat.		α Ph.—α Sat.	δ Ph.—δ Sat.
	m s	′ ″		m s	′ ″
June 2	−2 09.2	+10 22	June 18	−1 57.7	+ 9 14
4	8.6	10 15	20	55.9	9 04
6	7.2	10 07	22	54.1	8 54
8	5.7	9 59	24	52.2	43
10	4.2	50	26	50.2	33
12	2.7	41	26	48.2	22
14	2 01.1	32	28	48.2	22
16	−1 59.4	+ 9 23	30	−1 46.1	+ 8 10

VARIABLE STARS.

Minima of Variable Stars of Short Period.

[Calculated by D. C. Kazarinoff at Goodsell Observatory.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5h; Central Standard 6h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1919 June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8			15 2					
RT Sculptor.	31.5	−26 13	9.6—10.5	0 12.3	5 23;	13 15;	21 7;	28 23				
UU Androm.	38.5	+30 24	10.7—11.9	1 11.7	6 10;	13 20;	21 6;	28 17				
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	2 5;	9 16;	17 4;	24 15				
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	6 9;	18 14;	24 17;	30 20				
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	5 15;	12 18;	19 22;	27 1				
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	5 6;	12 2;	18 23;	25 20				
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	2 13;	9 17;	16 21;	24 1				
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	6 17;	15 12;	24 7;	27 5				
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	8 12;	16 11;	24 10;	27 2				
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6			22 6					
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	5 8;	16 19;	22 12;	28 6				
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	6 11;	13 6;	20 1;	26 20				
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	5 14;	13 11;	21 9;	29 7				
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	8 18;	17 1;	19 20;	25 9				
RV Persei	4 04.2	+33 59	9.5—11.0	1 23.4	8 17;	16 14;	24 12;	28 11				
RW Persei	13.3	+42 04	8.8—11.0	13 04.8	6 17;	19 22						
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	8 2;	17 13;	20 17;	27 0				
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1		10 22;	23 8					
TT Aurigae	5 02.8	+39 27	7.8— 8.7	0 16.0	1 5;	14 20;	21 12;	27 4				
RY Aurigae	11.5	+38 13	10.7—11.7	2 17.5	5 15;	13 20;	22 0;	30 5				
RZ Aurigae	42.9	+31 40	10.6—13.3	3 00.3	6 18;	18 19;	24 20;	30 20				
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	1 17;	10 9;	19 1;	27 17				
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	5 16;	16 2;	21 7;	26 12				
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2	6 12;	14 12;	22 13;	30 13				
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	6 16;	18 3;	23 20;	29 14				
U Columbae	6 11.2	−33 03	9.2—10.0	2 19.2	3 10;	14 15;	20 5;	25 19				
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8	5 3;	13 8;	21 12;	29 17				
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	8 0;	15 15;	23 5;	30 20				
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0		10 20;	23 1					
RU Monoc.	6 49.4	− 7 28	9.8—10.5	0 21.5	7 17;	14 21;	22 1;	29 5				
R Can. Maj.	7 14.9	−16 12	5.8— 6.4	1 03.3	6 23;	13 19;	20 14;	27 10				
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2	6 20;	16 4		25 11				
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	7 12;	14 3;	20 18;	27 8				
TX Gemin.	30.3	+17 8	10.0—11.9	2 19.2	6 10;	14 20;	23 5					
RR Puppis	43.5	−41 08	9.4—10.7	6 10.3	4 7;	17 4;	23 14;	30 1				
V Puppis	7 55.4	−48 58	4.1— 4.8	1 10.9	1 19;	16 8;	23 14;	30 21				
X Carinae	8 29.1	−58 53	7.9— 8.7	0 13.0	7 19;	15 22;	24 1;	29 11				
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	3 7;	12 19;	22 7					
RX Hydrae	9 00.8	− 7 52	9.1—10.5	2 6.8	2 14;	16 7;	23 3;	30 0				
S Velorum	29.4	−44 46	7.8— 9.3	5 22.4	1 19;	13 16;	19 14;	25 12				
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	4 13;	11 7;	18 1;	24 19				
RR Velorum	10 17.8	−41 36	10.0—10.9	1 20.5	6 5;	13 15;	21 1;	28 11				
SS Carinae	10 54.2	−61 23	12.2—12.8	3 07.2	5 8;	11 22;	18 13;	25 3				
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	8 14;	17 10		26 5				
RW Urs. Maj.	35.4	+52 34	10.3—11.4	7 07.9	6 13;	13 21;	21 5;	28 13				
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	4 18;	11 13;	18 8;	25 3				
RZ Centauri	12 55.6	−64 05	8.5— 8.9	1 21.0	4 20;	12 8;	19 20;	27 9				
RS Can. Ven.	13 06.3	+36 28	7.5—12.5	4 19.1	5 15;	10 10;	20 0;	29 14				
SS Centauri	13 07.2	−63 37	8.8—10.4	2 11.5	1 8;	8 18;	16 5;	23 15				
133926 Hydrae	13 39.0	−26 23	8.6—12.7	2 21.5	6 20;	12 15;	24 5;	30 0				
δ Librae	14 55.6	− 8 07	4.8— 6.2	2 07.9	2 6;	9 5;	23 4;	30 4				

Minima of Variable Stars of Short Period—Continued.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1919 June
	h m	° ′		d h	d h d h d h d h d h
U Coronae	15 14.1	+32 01	7.6— 8.7	3 10.9	2 17; 9 15; 23 10; 30 8
TW Draconis	32.4	+64 14	7.3— 8.9	2 19.3	4 9; 12 19; 21 5; 29 15
SS Librae	15 43.4	—15 14	9.3—11.5	0 18.4	2 1; 9 16; 17 8; 25 0
SW Ophiuchi	16 11.1	— 6 44	9.2—10.0	2 10.7	8 17; 16 1; 23 8; 30 17
SX Ophiuchi	12.6	— 6 25	10.5—11.2	2 01.5	7 10; 15 16; 23 22; 27 25
R Arae	31.1	—56 48	6.8— 7.9	4 10.2	4 7; 13 4; 22 0; 30 21
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1	7 9; 17 10 28 2
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	4 6; 11 1; 17 21; 24 15
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	2 17; 11 3; 19 12; 27 21
u Herculis	13.6	+33 12	4.6— 5.4	2 01.2	5 4; 11 8; 23 15; 29 19
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	7 21; 15 2; 22 7; 29 12
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	6 23; 14 8; 21 17; 29 1
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	1 4; 9 9; 17 13; 25 17
TX Scorpii	48.6	—34 13	7.5— 8.2	0 22.6	3 6; 10 19; 18 8; 25 21
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	6 1; 13 19; 21 13; 29 7
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	3 23; 11 23; 19 23; 27 22
WX Sagittae	53.6	—17 24	9.2—10.8	2 03.1	1 5; 9 18; 18 6; 26 19
WY Sagittae	17 54.9	—23 1	9.5—10.6	4 16.0	4 9; 13 17; 23 1; 27 17
SX Draconis	18 03.0	+ 58 23	9.3—10.5	5 04.1	5 17; 16 1; 21 5; 26 9
RS Sagittarii	11.0	—34 08	5.9— 6.3	2 10.0	5 14; 12 20; 20 2; 27 8
V Serpentis	11.1	—15 34	9.5—11.1	3 10.9	7 12; 14 9; 21 7; 28 5
RZ Scuti	21.1	— 9 15	7.4— 8.3	15 03.2	11 1 26 4
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	6 15; 13 19; 20 23; 28 3
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	1 6; 8 9; 22 14; 29 17
SX Sagittarii	39.7	—30 36	8.7— 9.8	2 01.8	8 20; 17 4; 25 11; 29 15
RR Draconis	40.8	+62 34	9.3—13	2 19.9	4 3; 12 15; 21 3; 29 14
RS Scuti	43.7	—10 21	9.3—10.3	0 15.9	4 8; 11 0; 24 6; 30 22
β Lyrae	46.4	+33 15	3.4— 4.1	12 21.8	11 22; 24 19
U Scuti	18 48.9	—12 44	9.1— 9.6	0 22.9	1 2; 8 17; 16 9; 24 0
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	7 23; 15 13; 23 3; 30 17
RV Lyrae	12.5	+32 15	11. —12.8	3 14.4	4 20; 12 0; 19 5; 26 10
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	9 14; 18 13; 23 0; 27 12
U Sagittae	14.4	+19 26	6.5— 9.0	3 09.1	3 10; 10 4; 23 17; 30 11
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	7 12; 14 21; 22 6; 29 14
TT Lyrae	24.3	+41 30	9.4—11.6	5 05.8	3 17; 14 5; 19 11; 29 23
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	3 6; 16 7; 22 20; 29 8
SY Cygni	19 42.7	+32 28	10 —12	6 00.2	6 17; 18 17; 24 17; 30 17
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	3 19; 17 2; 23 17; 30 8
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	7 11; 16 14; 25 18; 30 8
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	4 23; 13 9; 21 20; 30 6
RW Capric.	12.2	—17 59	8.8—10.6	3 09.4	3 2; 9 21; 23 10; 30 5
UW Cygni	19.6	+42 55	10.5—13	3 10.8	2 15; 9 12; 23 8; 30 5
V Vulpec.	32.3	+26 15	8.2—9.8	37 19.0	7 17
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	9 23; 19 13; 24 9; 29 4
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	5 19; 15 0; 24 5; 28 20
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	5 3; 12 15; 20 2; 24 14
WZ Cygni	49.3	+38 27	9.9—10.8	0 14.0	2 14; 10 5; 17 19; 25 9
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	5 14; 15 16; 25 19; 30 20
VV Cygni	21 02.3	+45 23	12.1—13.8	1 11.4	5 7; 12 16; 20 2; 27 11
AE Cygni	09.0	+30 20	10.8—11.4	0 23.3	5 15; 10 11; 20 4; 29 20
RY Aquarii	14.8	—11 14	8.8—10.4	1 23.2	6 16; 14 13; 22 10; 30 7
RT Lacertae	21 57.4	+43 24	9.1—10.5	5 01.7	2 23; 13 2; 23 6; 28 8
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3	19 18
RW Lacertae	22 40.6	+49 08	10.2—11.2	5 04.4	5 17; 10 21; 21 6; 26 11
TT Androm.	23 08.7	+45 36	11.3—12.6	2 18.4	7 14; 15 21; 24 4; 26 22
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.3	7 12; 15 0; 22 13; 30 2
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	6 12; 14 17; 22 23; 27 2

Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time. To obtain Eastern standard time subtract 5^h; Central standard time 6^h; etc.

Star	R. A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1919. June
	h m	° ′		d h	d h d h d h d h d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.2	36 13.7	7 10
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	1 17; 9 21; 18 0; 26 3
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	4 18; 12 12; 20 6; 28 0
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2	14 2 28 22
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	5 23; 13 21; 21 20; 29 19
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	6 22; 14 17; 22 12; 30 7
TU Persei	3 01.8	+52 49	11.4—12.2	0 14.6	8 20; 16 3; 23 10; 30 17
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	3 0 19 0
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	8 10; 17 0; 20 7; 25 1
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	5 11; 16 14; 27 17
RX Aurigae	4 54.5	+39 49	7.2— 8.1	11 15.0	7 8 18 23; 30 14
SX Aurigae	5 04.6	+42 02	8.0— 8.7	1 12.8	1 8; 8 23; 16 15; 24 7
SY Aurigae	05.5	+42 41	8.4— 9.5	10 03.3	1 5; 11 8; 21 12
Y Aurigae	21.5	+42 21	8.6— 9.6	3 20.6	2 4; 9 21; 17 14; 25 7
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	7 13; 18 15; 24 4; 29 16
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	8 10; 15 24; 23 14
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3	3 6 30 7
RT Aurigae	23.0	+30 33	5.1— 6.0	3 17.5	6 21; 14 8; 21 19; 29 6
RZ Camelop.	23.7	+67 06	11.0—13.0	0 11.5	2 5; 9 10; 16 15; 23 20
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	6 11; 14 9; 22 7; 30 5
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	4 10; 14 14; 24 17
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5	8 13 30 20
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	5 3; 13 2; 21 1; 29 0
V Carinae	8 26.7	−59 47	7.4— 8.1	6 16.7	6 21; 13 14; 20 7; 26 23
T Velorum	8 34.4	−47 01	7.6— 8.5	4 15.3	1 11; 10 18; 20 1; 29 8
V Velorum	9 19.2	−55 32	7.5— 8.2	4 08.9	1 6; 10 0; 18 17; 27 11
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 00.0	22 0
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	2 12; 16 2; 22 21; 29 16
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	4 6; 17 11; 24 2; 30 16
S Muscae	12 07.4	−69 36	6.4— 7.3	9 15.8	7 10; 17 2; 26 18
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	4 3; 12 2; 20 1 ; 28 1
T Crucis	15.9	−61 44	6.8— 7.6	6 17.6	7 8; 14 1; 20 19; 27 13
R Crucis	18.1	−61 04	6.8— 7.9	5 19.8	6 6; 17 21; 23 17; 29 13
S Crucis	12 48.4	−57 53	6.5— 7.6	4 16.6	3 8; 12 17; 22 2; 26 19
W Virginis	13 20.9	− 2 52	8.7—10.4	17 06.5	11 0 28 6
SS Hydrae	25.0	−23 08	7.4— 8.1	8 4.8	8 10; 16 15; 24 20
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	6 2; 13 2; 20 3; 27 3
ST Virginis	14 22.5	− 0 27	10.3—11.4	0 09.9	7 11; 15 16; 19 18; 23 21
V Centauri	25.4	−56 27	6.4— 7.8	5 11.9	2 17; 13 17; 24 16; 30 4
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	4 4; 11 17; 19 6; 26 19
RU Bootis	14 41.5	+23 44	12.8—14.3	0 11.9	3 13; 10 23; 18 9; 25 18
R Triang. Austr.	15 10.8	−66 08	6.7— 7.4	3 09.3	2 2; 15 15; 22 10; 29 5
S Triang. Austr.	15 52.2	−63 29	6.4— 7.4	6 07.8	1 15; 14 6; 20 14; 26 22
S Normae	16 10.6	−57 39	6.6— 7.6	9 18.1	9 12; 19 6 30 0
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	1 7; 10 3; 19 0; 27 21
RV Scorpii	16 51.8	−33 27	6.7— 7.4	6 01.5	2 18; 14 21; 20 23; 28 0
X Sagittarii	17 41.3	−27 48	4.4— 5.0	7 00.3	5 22; 12 22; 19 22; 26 23
Y Ophiuchi	47.3	− 6 07	6.1— 6.5	17 02.9	6 21 24 0
W Sagittarii	17 58.6	−29 35	4.3— 5.1	7 14.3	6 23; 14 13; 22 3; 29 18
Y Sagittarii	18 15.5	−18 54	5.4— 6.2	5 18.6	4 12; 16 1; 21 19; 27 14
U Sagittarii	26.0	−19 12	6.5— 7.3	6 17.9	8 5; 14 22; 21 16; 28 10
Y Scuti	32.6	− 8 27	8.7— 9.2	10 08.3	1 14; 11 22; 22 7
Y Lyrae	34 2	+43 52	11.3—12.3	0 12.1	2 7; 14 8; 20 9; 26 10
RZ Lyrae	39.9	+32 42	9.9—11.2	0 12.3	3 0; 15 7; 21 10; 27 13
RT Scuti	18 44.1	−10 30	9.1— 9.7	0 11.9	2 12; 14 10; 20 9; 26 7
κ Pavonis	18 46.6	−67 22	3.8— 5.2	9 02.2	1 17; 10 19; 19 21; 28 23

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1919. June							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	
U Aquilae	19 24.0	− 7 15	6.2— 6.9	7 00.6	7 23;	15 0;	22 1;	29 1				
XZ Cygni	30.4	+56 10	8.6— 9.3	0 11.2	3 22;	10 22;	17 22;	24 22				
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	6 11;	14 10;	22 10;	30 9				
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	7 2;	14 19;	22 11;	30 4				
η Aquilae	47.4	+ 0 45	3.7— 4.5	7 04.2	8 10;	15 14;	22 19;	29 23				
S Sagittae	51.5	+16 22	5.6— 6.4	8 09.2	7 6;	15 15;	24 0					
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	4 21;	11 4;	17 12;	23 20				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3	9 6		25 16					
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	3 7;	12 4;	21 1;	29 22				
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	7 13;	14 6;	21 0;	27 17				
RV Capric.	55.9	−15 37	9.2—10.1	0 10.7	4 7;	11 0;	17 17;	24 10				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4		13 10		28 3				
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	6 1;	13 22;	21 19;	29 15				
SW Aquarii	10.2	— 0 20	9.9—10.8	0 11.0	1 13;	15 8;	22 5;	29 3				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	5 1;	14 19;	24 12;	29 9				
Y Lacertae	22 05.2	+50 33	9.1— 9.6	4 07.8	4 4;	12 20;	21 11;	30 3				
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	2 16;	14 10;	24 3;	29 12				
Z Lacertae	36.9	+56 18	8.2— 9.0	10 21.1		10 6;	21 3					
RR Lacertae	37.5	+55 55	8.5— 9.2	6 10.1	2 3;	14 23;	21 9;	27 19				
V Lacertae	44.5	+55 48	8.5— 9.5	4 23.6	3 14;	13 13;	23 12;	28 12				
X Lacertae	22 45.0	+55 54	8.2— 8.6	5 10.7	3 11;	14 8;	25 5;	30 16				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	2 6;	13 3;	24 23;	29 11				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	1 21;	14 12;	20 19;	27 2				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	4 16;	16 19		26 23				
V Cephei	23 51.7	+82 38	6.0—7.0	0 23.9	7 15;	14 15;	21 14;	28 14				

NOTES FOR OBSERVERS.

Monthly Report of the American Association of Variable Star Observers, March, 1919.

Observers are cautioned to have due regard for the effect of Summer Time, when reporting the Greenwich Mean Time in tenths. One must merely consider the observation as made an hour earlier when reducing the decimal of a day.

After an interval of about one hundred days, U Geminorum, 074922, has again passed a maximum. Professors Young and Mitchell suspected a slight rise on April 2, and Mr. McAteer confirmed the maximum on April 6. Mr. McAteer also observed SS Cygni, 213843, at maximum on March 27. The next maximum of this star may be expected on or about May 1. χ Cygni, 194632, and R Scuti, *184205*, both require special attention, the former now on its rapid increase, and the latter probably dropping to minimum.

The following maxima for May are given from Harvard Circular 212:

043274	X Camelop.	May 9		*164319*	RR Ophiuchi	May 31
063558	S Lyncis	" 4		171723	RS Herculis	" 5
090024	S Pyxidis	" 15		181136	W Lyrae	" 1
124204	RU Virginis	" 13		182306	T Serpentis	" 1
142539	V Bootis	" 19		190967	U Draconis	" 29
150519	T Librae	" 8		194632	χ Cygni	" 23
151822	RS Librae	" 21		203847	V Cygni	" 14
160210	U Serpentis	" 27		235350	R Camelop	" 16
*161122*b	S Scorpii	" 13				

VARIABLE STAR OBSERVATIONS, March, 1919.

Feb. 0 = 2421990 Mar. 0 = 2422018 Apr. 0 = 2422049

001046
X Androm.
J.D. Est. Obs.
242
2037.6 10.1 V

001032
S Sculptoris
1948.6 7.0 Tp
57.5 7.0 δ_2
80.6 6.9 Tp
87.5 7.2 δ_2

001755
T Cassiop.
2021.6 < 11.0 B
40.6 10.0 M

002438a
T Sculptoris
1948.6 9.8 Tp
57.5 9.5 δ
80.6 9.5 Tp
87.6 9.6 δ_2

002546
T Phoenicis
1948.6 9.3 Tp
57.5 9.3 δ
69.6 10.6 Tp
80.6 10.7 Tp
87.6 11.4 δ_2

002833
W Sculptoris
1957.5 13.0 δ
69.6 12.9 Tp
85.6 13.0 δ

003179
Y Cephei
2041.5 12.9 Ba

004047
U Cassiop.
2041.5 < 13.1 Ba

004958
W Cassiop.
2019.6 11.3 Wh
21.6 11.1 B

010940
U Androm.
2026.5 < 11.3 B

011041
UZ Androm.
2021.6 < 12.5 B

011272
S Cassiop.
2021.6 12.6 B
41.5 13.1 Ba

012350
RZ Persei
J.D. Est. Obs.
242
2026.6 10.2 B
42.6 10.3 Y

014958
X Cassiop.
2026.6 11.2 B
40.6 12.5 M
42.6 12.8 Y

015354
U Persei
2021.6 10.2 B
39.6 9.0 Wh

021024
R Arietis
2037.6 9.0 Pt

021281
Z Cephei
2048.6 10.2 M

022150
RR Persei
2024.6 12.0 Yo
41.6 13.0 Ba
42.6 12.1 Y

022980
RR Cephei
2048.6 9.5 M

023133
R Trianguli
2036.6 6.1 Wh
39.5 6.7 B

024356
W Persei
2021.6 9.2 B
36.5 9.4 Pt
36.6 10.0 Wh
37.6 10.0 Mu
48.6 10.0 M

025751
T Horologii
1957.5 8.1 δ
80.6 9.1 Tp
89.6 9.8 δ
95.6 10.4 Tp

030514
U Arietis
2024.6 10.5 Y
32.6 8.2 Y
41.6 8.4 Ba

032043
Y Persei
J.D. Est. Obs
242
2026.6 9.4 B
36.5 9.5 Pt
37.6 9.6 Mu
48.6 9.5 M

032335
R Persei
2036.6 8.6 Pt
39.6 8.6 Wh

033362
U Camelop.
2048.6 8.2 M

034625
U Eridani
1980.6 10.5 δ
80.6 10.2 Tp
89.6 11.4 δ

035124
T Eridani
1949.6 9.5 Tp
62.8 10.1 δ
80.6 10.6 Tp
89.6 11.3 δ
90.1 11.2 Tp_2
95.6 11.2 Tp

040725
W Eridani
1949.6 9.1 Tp
62.8 9.6 δ
67.6 9.7 Tp
80.6 10.3 Tp
80.6 10.2 δ
89.6 10.4 δ
90.1 10.3 Tp_2
95.6 10.4 Tp

041619
T Tauri
2040.6 9.6 M

042215
W Tauri
2032.6 9.8 Yo
37.6 10.0 B
37.6 9.9 M
40.6 9.8 Mu
41.6 9.6 Ba
42.6 9.8 Y
44.5 10.2 Pi

042209
R Tauri
2032.6 10.3 Yo
36.6 10.7 B

R Tauri
J.D. Est. Obs.
242
2040.6 10.4
41.6 10.1 Ba
42.6 10.6 Y

042309
S Tauri
2041.6 < 13.4 Ba

043065
T Camelop.
2036.6 8.5 Wh
41.5 8.8 Ba
41.7 8.7 M
45.5 9.2 Pi

043274
X Camelop.
2036.6 11.7 B
39.6 11.4 Wh
41.5 11.0 Ba
41.7 11.4 M
42.6 11.2 Y
45.5 11.0 Pi

043263
R Reticuli
1962.8 8.0 δ_2
81.6 8.6 δ
81.6 8.5 Tp
87.6 8.8 δ_2
90.1 8.8 Tp_2
95.6 9.2 Tp
95.6 9.4 δ

043562
R Doradus
1962.8 6.3 δ
89.6 6.1 δ_2
90.1 5.4 Tp_2

043738
R Caeli
1962.8 9.4 δ
81.6 9.7 δ
81.6 9.7 Tp
89.6 10.2 δ
90.1 10.2 Tp_2
95.6 10.3 Tp

044349
R Pictoris
1962.8 9.2 δ
81.6 9.6 δ
81.6 9.7 Tp
89.6 9.3 δ
90.1 9.4 Tp_2
95.6 9.1 Tp
95.6 9.3 δ

044617
V Tauri
2032.6 9.1 Yo
44.5 8.9 Pi

045307
R Orionis
2024.6 11.4 Y
39.6 11.6 B

045514
R Leporis
2024.5 7.8 My
36.5 7.6 Pt
37.6 6.8 B
51.6 7.5 Pi

050003
V Orionis
2024.6 11.4 Y
37.6 12.5 B
42.5 13.0 Ba

050022
T Leporis
2037.6 9.3 B

050953
R Aurigae
2023.6 8.5 B
37.6 8.9 V
40.6 8.9 M
44.5 9.0 Pi
45.7 8.7 B

051247
T Pictoris
1962.8 12.8 δ
89.6 10.1
90.1 9.9 Tp_2
95.6 9.4 δ
96.6 9.4 Tp

051533
T Columbae
1962.8 11.2 δ
67.6 11.3 Tp
85.7 12.0 δ
90.1 12.3 Tp_2
95.6 12.2 Tp
95.6 12.0 δ

052036
W Aurigae
2040.6 10.4 M
40.6 10.9 Wh

052034
S Aurigae
2023.6 9.8 B
40.6 9.8 M
40.6 9.6 Wh
44.5 9.8 Pi
45.6 10.0 B

VARIABLE STAR OBSERVATIONS, March, 1919—Continued.

052404
S Orionis

J.D. 242	Est.	Obs.
2039.6	9.5	B
40.6	9.2	M
42.5	8.7	Ba

053068
S Camelop.

2041.7	9.6	M
43.6	8.7	Wh
45.5	8.7	Pi

*053005*a
T Orionis

2032.6	9.9	B
36.6	9.5	Wh
40.6	9.3	M
44.6	10.0	Pi

053326
RR Tauri

2037.6	12.0	B
40.6	11.0	M

053531
U Aurigae

2023.6	10.0	B
24.6	10.6	Y
37.6	10.8	Y
40.7	11.1	M
45.7	10.8	B

054319
SU Tauri

1991.8	9.5	Ba
95.6	9.5	
2021.7	9.4	B
24.6	9.6	Wh
24.6	9.5	Y
28.6	9.4	B
30.5	9.5	
32.6	9.4	
34.6	9.4	
36.6	9.5	
36.6	9.5	Wh
37.6	9.4	B
37.6	9.5	V
38.6	9.4	B
39.6	9.4	
40.7	9.4	B
40.7	9.4	M
41.5	9.5	Ba
42.5	9.4	
42.6	9.4	B
42.6	9.5	Y
43.6	9.5	B
44.5	9.5	Pi
45.6	9.5	B

054615a
Z Tauri

J.D. 242	Est.	Obs.
2042.6	<13	Y

054615b
RS Tauri

2024.6	8.6	Y
42.6	9.0	

054615c
RU Tauri

2024.6	11.5	Y
42.6	11.0	

054629
R Columbae

1962.8	9.8	δ
87.6	9.5	δ_2
90.1	9.1	Tp_2
95.6	9.0	Tp
95.6	9.6	δ

054974
V Camelop.

1991.8	12.6	Ba
2040.7	12.8	M
41.5	13.4	Ba
42.6	12.8	Y

054920
U Orionis

2034.6	11.4	B
40.7	10.6	M
44.5	10.8	Pi

055353
Z Aurigae

2040.6	9.3	M
40.7	9.8	B
44.5	10.0	Pi

055686
R Octantis

1962.8	12.5	δ
89.6	11.9	Tp
89.7	11.8	δ
95.6	11.5	
95.6	11.6	Tp

060450
X Aurigae

2039.6	10.2	Wh
40.6	10.3	M
40.7	10.0	B
42.5	10.3	Ba
44.5	10.6	Pi

060547
SS Aurigae

1991.8	<13.0	Ba
95.6	11.4	
2024.6	<13.2	Y
29.5	10.8	

SS Aurigae

J.D. 242	Est.	Obs.
2030.6	11.6	Jk
32.6	12.0	Y
37.6	<11.4	V
39.6	<12.5	B
41.5	<13.5	Ba
42.5	<13.5	
42.6	<13.3	Y
44.5	<12.4	Pi

061647
V Aurigae

2040.7	12.0	B

061702
V Monoc.

2044.6	<11.1	Pi

063159
U Lyncis

2024.6	10.1	Y
37.6	10.2	B
40.7	10.3	M
42.5	10.0	Ba

063308
R Monoc.

2037.6	11.7	B

063558
S Lyncis

2024.6	10.9	Wh
40.6	9.9	
40.7	9.9	M
42.5	10.0	Ba
44.5	9.9	Pi

064030
X Gemin.

2042.5	11.5	Ba

065111
Y Monoc.

2024.6	11.5	Y
32.6	11.4	B
42.5	12.5	Ba

065208
X Monoc.

2039.5	7.6	My_2
47.5	7.5	My

065355
R Lyncis

2037.6	10.2	B
40.7	10.0	M
42.6	10.1	Y

070122a
R Gemin.

2036.7	10.7	B
39.6	10.8	Wh
41.7	10.4	M
44.6	10.8	Pi

070122b
Z Gemin.

J.D. 242	Est.	Obs.
2041.7	12.3	M

070122c
TW Gemin.

2036.7	8.2	B
41.7	8.4	M

070109
V Can. Min.

2042.6	<13.5	Ba

070310
R Can. Min.

2032.7	8.2	B

071044
L_2 Puppis

1989.7	4.3	δ

071713
V Gemin.

2039.6	12.0	Wh

072106
Nova Monoc.

1962.8	12.5	δ
67.6	12.6	Tp
85.7	12.9	δ
96.6	12.9	δ_2
97.6	12.8	Tp

072708
S Can. Min.

2021.5	12.5	B
41.6	12.4	M
42.6	12.6	B

*072820*b
Z Puppis

2044.6	<11.5	Pi

072811
T Can. Min.

2024.6	<13.7	Y
41.6	12.6	M

073508
U Can. Min.

2022.5	10.0	Pi
24.6	9.7	Y
41.6	9.7	M
44.6	9.5	Pi

073723
S Gemin.

2036.7	<11.7	B

074323
T Gemin.

2038.6	12.2	B
39.6	12.3	Wh
51.6	11.7	M
44.6	12.0	Pi

074922
U Gemin.

J.D. 242	Est.	Obs.
1991.8	<13.5	Ba
95.6	<13.5	
2019.7	<13.3	Yo
24.6	<12.8	
24.6	<13.7	Y
26.7	<12.4	Yo
37.6	<11.7	V
40.7	<12.4	M
42.6	14.0	Ba
42.6	<13.3	Y
44.6	<12.3	Pi
50.7	13.3	Yo

075612
U Puppis

2037.6	11.7	B

081112
R Cancri

2036.5	8.2	Pt
37.6	7.8	Wh
44.6	7.9	Pi
48.6	7.3	M

081617
V Cancri

2019.7	8.8	Yo
23.6	8.1	Pt
32.7	8.5	B
37.6	8.8	Wh
44.6	9.5	Pi
48.6	8.7	M

082405
RT Hydrae

2040.6	7.8	B

083019
U Cancri

2037.6	9.5	V

084803
S Hydrae

2023.6	11.8	B
40.6	11.3	
44.7	11.3	Pi

085008
T Hydrae

2036.5	8.7	Pt
44.7	8.5	Pi

085120
T Cancri

2037.6	9.8	Wh

090151
V Urs. Maj.

2039.6	10.7	B
46.9	9.8	M

VARIABLE STAR OBSERVATIONS, March, 1919—Continued.

091868
RW Carinae

J.D.	Est.	Obs.
242		
1962.8	13.5	δ
92.6	12.9	

092962
R Carinae

1950.5	4.8	δ_2
62.8	5.1	δ
69.6	5.3	Tp
87.7	6.4	δ_4
89.7	6.2	Tp
95.6	6.7	
95.6	6.9	δ_2

093014
X Hydrae

2044.7	11.2	Pi

093178
Y Draconis

2042.6	9.9	Y

093934
R Leo. Min.

2023.6	7.9	B
23.6	7.8	Pt
44.6	8.7	Pi
45.6	8.5	B

094023
RR Hydrae

1987.7	9.8	δ_2
95.7	9.8	δ
95.7	9.9	Tp

094211
R Leonis

2023.6	8.4	B
25.8	8.9	M
36.5	8.8	My
36.5	8.5	Pt
37.7	8.4	Mu
39.6	7.6	Wh
44.6	7.5	Pi
45.6	7.3	B
47.5	7.0	My

094262
l Carinae

1962.8	4.3	δ
69.6	4.5	Tp
87.7	3.8	δ_2
89.6	4.2	Tp
95.6	4.0	
95.6	4.2	δ

094622
Y Hydrae

2037.6	7.2	Pt
44.6	7.0	Pi

095421
V Leonis

J.D.	Est.	Obs.
242		
2023.6	12.8	B
45.6	12.8	

100661
S Carinae

1950.5	6.7	δ
62.8	7.0	
69.6	7.1	Tp
81.6	8.9	
81.6	8.5	δ
89.3	9.0	δ_3
89.6	9.0	Tp
95.7	9.4	
95.7	9.1	δ

103212
U Hydrae

1989.7	5.6	δ

103769
R Urs. Maj.

2024.5	8.1	My
25.9	9.0	M
37.6	7.5	Pt
37.7	8.0	Mu
39.5	7.8	My_3
39.6	7.7	B
42.5	7.6	Ba
45.5	8.0	Pi
48.6	7.8	My_2

104620
V Hydrae

2037.6	7.0	Pt
44.7	7.0	Pi

104814
W Leonis

2023.6	12.2	B
24.6	11.7	Y
25.8	12.4	M

110506
S Leonis

2025.8	11.5	M

114441
X Centauri

1987.7	13.1	δ_2
89.6	12.9	Tp
97.6	13.5	
97.7	13.4	δ

115919
R. Com. Ber.

2044.6	< 11.4	Pi

120012
SU Virginis

2037.6	9.6	V

120905
T Virginis

J.D.	Est.	Obs.
242		
1991.8	10.1	Ba
2039.7	12.0	B

121418
R Corvi

1991.8	10.4	Ba
91.8	10.4	δ
2025.8	11.3	M
39.6	12.1	B

122001
SS Virginis

1991.8	6.5	Ba
2039.7	7.9	B
41.7	9.3	M

122532
T Can. Ven.

2038.9	12.4	M
40.6	12.2	Wh
44.7	12.1	Pi

122803
Y Virginis

1991.8	9.4	Ba
2026.7	10.8	B

123160
T Urs. Maj.

2023.6	6.9	Pt
24.6	6.8	Wh
24.6	6.8	Y
25.9	7.4	M
26.7	7.0	B
37.7	7.6	Mu
42.5	7.5	Ba
45.5	7.5	Pi

123307
R Virginis

1991.8	10.1	Ba
2026.7	7.9	B
36.6	7.4	Pt
41.7	6.6	M
44.7	7.1	Pi

123459
RS Urs. Maj.

2042.5	< 13.5	Ba

123961
S Urs. Maj.

2023.6	7.7	Pt
24.6	7.4	Wh
24.6	8.2	Y
25.9	8.4	M
26.6	7.8	B
37.7	8.4	Mu
37.7	8.0	V
42.5	8.3	Ba
45.5	9.0	Pi

124204
RU Virginis

J.D.	Est.	Obs.
242		
1991.8	13.2	Ba
2044.7	12.2	Pi

124606
U Virginis

1991.8	7.5	Ba
2027.9	8.6	Pt
41.7	9.1	M
44.7	9.2	Pi
45.6	9.5	B

131283
U Octantis

1980.6	11.7	δ
80.6	11.9	Tp
87.7	11.8	δ_2
90.1	11.9	Tp_2
95.6	12.0	Tp
95.6	12.0	δ

132202
V Virginis

1991.8	9.2	Ba

132706
S Virginis

1991.8	5.9	Ba
2027.9	7.5	Pt
41.7	7.0	M
44.7	7.8	Pi

133273
T Urs. Min.

2045.8	10.8	V
46.9	10.7	M

133633
T Centauri

1962.8	7.6	δ
88.7	6.4	δ_2
89.6	6.2	Tp
95.6	6.0	Tp

134236
RT Centauri

1088.7	9.4	δ_2
89.6	9.3	Tp
96.6	9.6	Tp_2

134440
R Can. Ven.

2024.6	11.2	Wh
25.8	11.3	M
36.6	11.7	B
40.7	11.4	M
42.6	11.5	Y
43.6	11.3	Wh
45.6	11.6	Pi

134677
T Apodis

J.D.	Est.	Obs.
242		
1962.8	< 13.2	δ
97.6	12.7	Tp
97.7	12.6	δ

135908
RR Virginis

1991.8	< 13.5	Ba

140113
Z Bootis

1991.8	10.0	Ba
2029.8	11.5	M

140512
Z Virginis

1991.8	9.9	Ba

140528
RU Hydrae

1888.7	12.0	δ_2
89.6	11.8	Tp
96.7	12.0	Tp_2

140959
R Centauri

1962.8	7.5	δ_2
80.6	7.5	δ
80.6	7.5	Tp
87.0	7.4	δ_3
89.7	6.7	Tp
95.6	6.6	

141567
U Urs. Min.

2021.7	11.9	B
24.6	11.9	Wh
44.5	11.4	Pi
45.6	11.6	B
46.9	11.2	M

141954
S Bootis

2046.9	< 12.0	M

142205
RS Virginis

1991.8	12.7	Ba

142584
R Camelop.

2021.7	12.4	B
39.6	10.4	Wh
42.6	10.3	B
45.5	10.4	Pi

142539
V Bootis

1991.8	10.5	Ba
2029.8	9.9	M
37.7	8.9	Pt
43.7	9.1	Wg
45.6	9.0	Pi

VARIABLE STAR OBSERVATIONS, March, 1919—Continued.

143227
R Bootis
J.D. Est. Obs.
242
1991.8 10.0 Ba
2029.8 12.2 M

144918
U Bootis
1991.8 11.1 Ba
2029.8 11.4 M

145254
Y Lupi
1991.7 13.3 δ
96.6 13.4 Tp_2

150018
RT Librae
1991.8 < 14.0 δ

150519
T Librae
1991.8 < 13.0 Ba

150605
Y Librae
1991.8 8.0 Ba

151520
S Librae
1991.8 9.3 δ
91.9 8.8 Ba

151731
S Cor. Bor.
1991.8 5.9 Ba
2029.8 7.6 M
38.7 8.5 Pt
45.8 8.8 V

151714
S Serpentis
1991.9 11.2 Ba
2029.8 12.1 M

151822
RS Librae
1991.8 12.8 δ
91.9 12.0 Ba

152714
RU Librae
1991.9 9.6 Ba

152849
R Normae
1989.7 7.3 Tp
91.7 7.8 δ
96.7 7.6 Tp_2

153378
S Urs. Min.
242
J.D. Est. Obs.
2021.7 9.9 B
24.6 9.5 Wh
38.8 9.3 M
45.6 10.2 B
45.6 10.4 Pi
45.8 10.4 V

153654
T Normae
1989.7 11.6 Tp
91.7 10.7 δ
96.7 10.3 Tp_2

154428
R Cor. Bor.
1991.8 6.5 Ba
2019.7 6.2 Yo
19.9 6.1 Pt
25.8 6.0 M
27.9 6.2 Pt
29.7 6.3 Pt
29.8 6.0 M
37.7 5.9 Pt
38.7 5.8
38.8 6.0 M
38.8 6.4 Mu
40.7 6.2 Pt
41.7 6.2
42.6 6.0 Ba
42.7 6.2 Pt
42.7 6.1 Wg
43.7 6.4
45.6 6.3 Pt
45.9 6.1 V
46.7 6.2 Pt
47.7 6.1 Wg
49.9 6.3 Pt
51.7 6.0 Pi

154536
X Cor. Bor.
1991.8 9.0 Ba
2025.8 10.2 M
45.9 11.3 V

154639
V Cor. Bor.
1991.8 7.3 Ba
2025.8 8.6 M

154615
R Serpentis
1991.9 11.0 Ba
2027.9 8.2 Pt
29.8 8.2 M
45.9 7.7 V

155229
Z Cor. Bor.
1991.8 12.3 Ba
2029.8 < 12.5 M

155947
X Herculis
242
J.D. Est. Obs.
1991.9 5.8 Ba

155823
RZ Scorpii
1991.9 10.0 Ba

160118
R Herculis
1991.9 13.2 Ba

160210
U Serpentis
1991.8 < 12.5 Ba
2025.9 12.0 M

160625
RU Herculis
1991.8 11.3 Ba
2038.8 8.2 M

161138
W Cor. Bor.
1991.8 10.2 Ba
2025.8 8.2 M

161122a
R Scorpii
1991.9 < 13.0 Ba

161122b
S Scorpii
1991.9 < 13.0 Ba

161122c
T Scorpii
1991.9 10.5 Ba

161607
W Ophiuchi
1991.9 < 13.0 Ba

162119
U Herculis
1991.9 9.9 Ba
2025.8 11.4 M

162112
V Ophiuchi
1991.9 9.2 Ba

162807
SS Herculis
1991.8 11.0 Ba

162816
S Ophiuchi
1991.9 12.8 Ba

163172
R Urs. Min.
2021.7 9.5 B
38.8 9.5 M
42.6 9.8 B
45.6 10.0 Pi

163137
W Herculis
242
J.D. Est. Obs.
1991.9 11.5 Ba
2025.8 9.3 M
40.7 8.9 Pt
45.9 8.7 V

163266
R Draconis
2024.6 11.3 Wh
38.8 12.3 M

164055
S Draconis
1991.9 8.2 Ba
2025.8 8.8 M
27.9 9.1 Pt

164319
RR Ophiuchi
1919.9 < 12.2 Ba

164715
S Herculis
1991.9 12.3 Ba
2025.8 12.5 M

164844
RS Scorpii
1991.8 7.5 δ
95.6 7.4 Tp

165030
RR Scorpii
1991.7 5.4 δ
95.8 5.8 Tp

165631
RV Herculis
1991.8 12.0 Ba
2025.8 < 12.2 M

170215
R Ophiuchi
1991.9 12.0 Ba

170627
RT Herculis
1991.8 < 13.0 Ba

171401
Z Ophiuchi
2045.9 7.7 V
46.9 8.1 Pt

171723
RS Herculis
1991.8 < 12.5 Ba

172486
S Octantis
1962.8 13.0 δ
67.6 13.1 Tp
97.6 13.9 Tp
97.7 12.9 δ

172809
RU Ophiuchi
242
J.D. Est. Obs.
1991.9 10.0 Ba
2029.9 9.8 M

175111
RT Ophiuchi
1991.9 < 12.8 Ba

175458a
T Draconis
2038.8 10.2 M

180363
R Pavonis
1991.8 8.3 δ
95.7 8.1 Tp

180531
T Herculis
2025.9 9.1 M
27.9 8.4 Pt
45.9 7.6 V

181136
W Lyrae
2027.9 10.0 M_2

181103
RY Ophiuchi
2038.8 8.4 M

182133
RV Sagittarii
1991.8 8.2 δ

182224
SV Herculis
1991.9 9.6 Ba
2046.9 10.7 M

182306
T Serpentis
2046.9 11.0 M

183225
RZ Herculis
1991.9 < 12.5 Ba

183308
X Ophiuchi
2046.9 7.8 M

184243
RW Lyrae
2029.9 < 12.3 M

184205
R Scuti
1991.9 5.2 Ba
2019.9 5.5 Pt
27.9 5.2
29.9 5.0 M
40.9 5.0
45.9 5.8 Pt
49.9 5.9

VARIABLE STAR OBSERVATIONS, March, 1919—Continued

184300
Nova Aquilae
J.D. Est.Obs.
242
2019.9 6.2 Pt
27.9 6.2
29.9 6.2 M
45.9 6.3 Pt
45.9 6.3 V
49.9 6.3 Pt

190529a
V Lyrae
2029.9 < 12.4 M

190926
X Lyrae
2029.9 9.3 M

190925
S Lyrae
1991.9 13.8 Ba

191033
RY Sagittarii
1991.8 6.6 δ

191133
— Sagittarii
1991.8 9.2 δ

191350
TZ Cygni
1991.9 11.0 Ba

191637
U Lyrae
2029.9 9.7 M

192928
TY Cygni
J.D Est.Obs.
242
2029.9 10.3 M

193449
R Cygni
1991.9 9.0 Ba
2022.0 11.0 M

193732
TT Cygni
2045.9 8.2 Pt

193972
T Pavonis
1948.5 13.0 δ
62.5 13.7
97.7 13.9

194048
RT Cygni
1991.9 9.0 Ba
2022.0 11.3 M

194348
TU Cygni
1991.9 11.8 Ba
2022.0 < 12.4 M

194632
χ Cygni
1940.9 10.6 M

194659
S Pavonis
1948.5 7.4 δ_2
50.5 7.7
91.8 8.5 δ

200357
S Cygni
J.D. Est.Obs.
242
2029.9 < 12.4 M

200647
SV Cygni
2029.9 8.0 M

200938
RS Cygni
2027.9 8.6 Pt
29.8 8.8 M

201130
SX Cygni
2029.9 < 12.0 M

201139
RT Sagittarii
1949.5 8.6 δ_2

201647
U Cygni
2029.9 10.4 M

202240
U Microscopii
1948.5 13 δ

202539
RW Cygni
2029.9 9.4 M

202954
ST Cygni
2029.9 12.3 M

202946
SZ Cygni
J.D. Est Obs.
242
1991.9 8.8 Ba
2029.9 9.6 M
45.9 9.4 Pt

203226
V Vulpeculae
2019.9 8.9 Pt
29.9 8.7 M

203847
V Cygni
2029.9 10.1 M

205627
RR Capricorni
1949.5 11.9 δ_2

210868
T Cephei
2027.9 6.2 Pt

212030
S Microscopii
1949.5 13.1 δ_2

213843
SS Cygni
1991.9 11.0 Ba
2019.5 9.4 Y
19.9 9.5 Pt
21.5 10.4 Y
29.9 11.5 M
38.9 11.5
45.9 9.2 Pt
46.9 9.4 M
46.9 9.5 Pt

213937
RV Cygni
J.D. Est.Obs.
242
2019.9 7.8 Pt
38.9 8.0 M

214247
R Gruis
1962.5 13.3 δ

221948
S Gruis
1948.5 13.4 δ
62.5 14.2

223462
T Tucanae
1948.5 10.7 δ
49.6 11.1 Tp
57.5 11.6 δ
87.5 13.0 δ_2

232746
V Phoenicis
1948.5 13.8 δ
62.5 13.5
87.5 12.9 δ_2

235053
RR Cassiop.
2021.6 < 11.8 B

235150
R Phoenicis
1948.5 11.2 δ
49.6 11.4 Tp
57.5 10.6 δ
87.5 9.6 δ_2

235939
SV Androm.
2021.5 9.5 Y

No. of Observations 769. No. of Stars Observed 247. No. of Observers 15.

Mr. H. R. Schulmaier, of Berwick, Maine, the Historian of the Association, requests that all who have failed to send him their information cards will kindly do so at an early date. Little progress can be make in the statistics until a majority of these cards have been received.

President Bancroft communicates an excellent list, after a silence of several months.

It is hoped that others who were formerly so energetic in observing may be induced to take up the work again; there are many causes for distraction, but the stars keep right on varying.

Dr. William H. Woglom, of New York City, joins the active list this month, and his observations are designated by "Wg". Also Miss Jenkins, of Mount Holyoke College, contributed; her designation is "Jk".

Rev. T. C. H. Bouton has returned to Hudson, New Hampshire, from St. Petersburg, Florida.

An example has occurred this month which shows the bond of interest and the usefulness of the observations of our members. At the same time, Mr. Dawson in

Argentina and Mr. Bancroft in New Jersey were making estimates of R Corvi, *121418*, with exactly the same result.

The following observers contributed to this report:—Messrs. Bancroft, Bouton, Dawson, McAteer, Mundt, Murray, Peltier, D. B. Pickering, Tapia, Vrooman, Whitehorn, Woglom, and Yont, and Misses Jenkins and Young.

IDA E. WOODS.
Acting Secretary.

COMET AND ASTEROID NOTES.

The Asteroids (588) Achilles and (659) Nestor.—A card from Professor Elis Strömgren, director of the Copenhagen Observatory, communicates the following observations of two of the asteroids of the Trojan Group by Professor Max Wolf of Königstuhl, Germany:

	Königstuhl M. T.		α		δ		Mag.
		h m	h	m	°	′	
(588) Achilles	1919, March 1	12 10.7	11	45.1	−7	18	14.5
(659) Nestor	1919, March 7	10 51.5	11	11.1	+5	36	15

These two planets are thus "secured." They are always so faint that there was danger of their being lost. As there are only four known asteroids of the Trojan Group (with distances practically equal to that of Jupiter) it is important that as many observations of them as possible be obtained, in order that their peculiar movements may be studied as thoroughly as possible.

Reduction to Apparent Place for Asteroids and Comets.—In the *Astronomical Journal* No. 750 Mr. Ernest Clare Bower of the U. S. Naval Observatory suggests that the reduction to apparent place of comparison stars used in comet and asteroid observations is unnecessary, since the computer always uses the mean place of the object. The difference between the reduction of the star to apparent place and of the object to mean place is so small as to be negligible in most cases, and where great accuracy is required the difference may be computed by differential formulae with less labor.

It should be noted, however, that *planetary aberration cannot be omitted.* If, as is usual, the computer reduces the time of observation back to the time the light left the planet (or comet), the observed mean place must be changed by the amount of the annual aberration of a star in that position, with the sign changed.

COMMUNICATIONS.

The Brightness of the Moon at Various Phases.—I had occasion the other day to consider the brightness of the moon at various phases, referred to the mean full moon as standard, and here communicate the results I obtained, partly for the interest they may have of themselves, and partly in the hope that through some reader I may find the cause of the discrepancy between my results and a statement that I had previously seen.

In my solution I adopted the following notation:

S = the Sun's apparent semidiameter,
s = the Moon's apparent semidiameter,
S_0 and s_0 their respective mean semidiameters,
ϕ = the selenocentric latitude,
θ = the selenocentric longitude, counted from the bright limb towards terminator,
t = the value of θ for the terminator,
k = an arbitrary constant,
dA = the element of area comprised between the parallels ϕ and $\phi+d\phi$ and the meridians θ and $\theta+d\theta$,
B= the brightness of the moon at any phase, that of the mean full moon being 1;

and made the following assumptions:

a) That the distance of the moon from the sun is the same as the distance of the earth from the sun (which cannot introduce so much as 0.005 error);

b) That the moon's albedo is constant over the disk and that the light reflected is diffused in all directions according to the same law as for a self-luminous surface;

c) That the effects of the inclinations of the moon's orbit and equator to the ecliptic are negligible, and

d) That the sun's emission is constant.

With these assumptions the problem takes the form of a relatively simple integration.

Our element of area is, by definition,

$$dA = s^2 \cos\phi \, d\theta \, d\phi.$$

Its apparent extension on the celestial sphere will be dA multiplied by the cosine of the angle between the normal to the surface and the line from the point under consideration to the earth, or

$$dA \cos z = s^2 \cos^2\phi \sin\theta \, d\theta \, d\phi.$$

Its brightness will depend both on the distance from the sun and on the inclination to the sun's rays. The effect of this latter can be expressed by the cosine of the angle between the sun's rays and the normal to the surface, that of the former, using assumption a), is expressed by the apparent size of the sun, or, neglecting numerical constants, by the square of the sun's semidiameter. Our element of brightness thus becomes

$$dB = k \, S^2 \, s^2 \cos^3\phi \sin\theta \sin(t-\theta) \, d\theta \, d\phi.$$

Having the element of brightness, we may integrate with respect to the two coördinates. First, with respect to ϕ from pole to pole, or between the limits $-\pi/2$ and $+\pi/2$, the brightness of the lune between meridians θ and $\theta+d\theta$ is given by

$$\frac{4}{3}\, k\, S^2\, s^2 \sin\theta \sin(t-\theta)\, d\theta;$$

and second, with respect to θ from the bright limb to the terminator, or between the limits θ and t, we have the total brightness,

$$B = \frac{2}{3}\, k\, S^2\, s^2\, (\sin t - t\cos t)\,.$$

To evaluate our constant, we observe that for the mean full moon $B = 1$,

$$S = S_0,\quad s = s_0 \text{ and } t = \pi.$$

Consequently,

$$1 = \frac{2}{3}\, k\, S_0^2\, s_0^2\, \pi, \quad k = \frac{3}{2\, S_0^2\, s_0^2\, \pi}$$

and

$$B = \frac{S^2\, s^2 (\sin t - t\cos t)}{S_0^2\, s_0^2\, \pi}\,.$$

If we neglect the distances we have

$$B = f(t) = \frac{1}{\pi}\,(\sin t - t\cos t),$$

values of which for each 10° are given in the following table:

t	$f(t)$	t	$f(t)$	t	$f(t)$
10°	0.001	70°	0.166	130°	0.708
20	0.004	80	0.236	140	0.800
30	0.015	90	0.318	150	0.881
40	0.034	100	0.410	160	0.944
50	0.065	110	0.508	170	0.985
60	0.109	120	0.609	180	1.000

To take into account the distances, it is only necessary to multiply the tabular quantities by the expression $\frac{S^2\, s^2}{S_0^2\, s_0^2}$, or with somewhat closer approximation, by $\frac{s^2}{r^2\, s_0^2}$, in which r is the true distance of the moon from the sun in terms of the astronomical unit.

From the above it appears that, if the assumptions made be tenable, the brightness of the moon at the "quarter" phase is nearly one third of the brightness at full. I have somewhere seen the statement that the relation is *one-twelfth*, tho I do not now remember exactly where I saw it. I would be very glad to have the cause of the discrepancy explained, and if it lie in some of my assumptions or computations, to know which is at fault.

BERNHARD H. DAWSON.

Observatory, LaPlata,
January 30, 1919.

GENERAL NOTES.

Sir William Crookes, the famous physicist and chemist, died on April 4, 1919, in his eighty-seventh year.

Mme. Camille Flammarion (Sylvie Pétiaux-Hugo), wife of the noted French astronomer and colaborer with him in much of his astronomical work, died on February 23, 1919, at the age of 82 years. Madame Flammarion was awarded the Janssen Prize in 1902 in recognition of her astronomical work and her services in behalf of the Astronomical Society of France, and the Observatory of Juvisy. She was the founder of a prize for women (Prix des Dames). She was the author of a charming novel under the pseudonym of Sylvio Hugo. In later years she was active in promoting an association of women advocating peace and disarmament (L'Association la Paix et le Désarmement par les femmes).

Professor Charles Leander Doolittle, former director of the Flower Observatory of the University of Pennsylvania, died on March 1, 1919, at the age of 75. He was professor of Mathematics and Astronomy at Lehigh University for twenty years (1875-95), and occupied a similar chair at the University of Pennsylvania until the time of his retirement from active work, being succeeded by his second son, Eric Doolittle. He is survived by four sons and one daughter. One son, Captain Gilbert Doolittle, was killed in France in September last.

Professor Doolittle did much valuable work with the Zenith Telescope at both the Sayre and Flower Observatories in the study of the variation of latitude.

Dr. H. D. Curtis, absent almost continuously from Mount Hamilton since August, 1917, at present head of the optical department in the Bureau of Standards, Washington, D. C., will return to his astronomical duties about May 1st. (*Pub. A. S. P.*, April, 1919.)

Professor William H. Wright, absent from Mount Hamilton since January, 1918, chiefly on indirect war service in the Students' Observatory, Berkeley, and during the last quarter of 1918 in the United States Government Artillery service, Aberdeen, Maryland, is again in the Astronomical Department at Berkeley. It is expected that he will return to Mount Hamilton about July 1st. (*Pub. A. S. P.*, April, 1919.)

Mr. William H. Ried of Cape Town, South Africa, has been awarded the Donohoe Comet Medal of the Astronomical Society of the Pacific, for his discovery of Comet *a* 1918. Professor Campbell states that "Mr. Reid is an enthusiastic comet seeker. He has found several comets, but the comet of last June is the only one of which he has been the earliest discoverer. His observatory is equipped with a 4-inch Alvan Clark refractor and a 6-inch Cooke refractor."

Mr. C. D. Shane, formerly Fellow in the Lick Observatory, who resigned in August, 1917, to engage in the service of the United States Shipping Board as instructor in navigation schools, has returned to his fellowship at Mount Hamilton. (*Pub. A. S. P.*, April, 1919.)

Dr. Paul Merrill who was an assistant in the U. S. Bureau of Standards during the past two years, has accepted a position with the Mount Wilson Observatory, beginning his work there in January last.

Northern Lights on the Morning of March 28.—The following description, of a brilliant aurora, by Mr. John H. Darling, of Duluth, Minnesota, is clipped from the *Duluth Herald* of March 29, 1919. The interview with the reporter of the Herald took place on March 28.

"Early this morning, between the hours of 1 and 3 o'clock a fine aurora, or northern lights, illuminated the skies, making a display which occurs only rarely on such a scale. Possibly it was present also in the earlier hours of the night but when I first looked at the sky about 1:15 the lights were going strong.

"Large flashes or waves of white light, of unusual size and rapidity of movement rushed upward in groups from a number of directions, from the East, Northeast, Northwest and West, and less strongly from the Southwest and South. The groups would often unite and spread over a wide area. They were most active from 1:30 to 1:45, and changes in form and locality occurred with great rapidity.

"The large light waves burst out so suddenly and so near to me apparently that I was really startled. It reminded me of flames from a large burning building or immense bonfire but on an incomparably greater scale. It made me wish that a battery of movie cameras might be used to reproduce the animated scene. This, however, would be impossible with the present development of the art as the light of the aurora is too faint to impress the sensitive film.

"The waves of light coming from the various directions met overhead. Their convergent point was poorly defined on account of the agitation of the waves, but I estimated it roughly as about 10 deg. from the zenith and 20 deg. east of south. A large arch of light spanned the northern sky, springing from points in the horizon about east and northwest. Some vertical streamers or columns of light of a more quiet and stationary form were seen in the northeast and other directions. No pronounced coloring was noticeable. During the last hour, 2 to 3 o'clock, the display diminished in brilliancy, leaving some distant white cloudy horizontal streaks of light in the northeast. The weather was clear, calm, cool and the sky moonless. It is only on moonless nights that the northern lights can be well seen. The lights are believed to be electrical discharges, induced by the earth's magnetism, darting through the thin upper strata of the atmosphere, sometimes to a height of several hundred miles."

International Societies and the War.—One of the regrettable results of the war has been the necessary cessation of intercourse between scientific men of the contending nations. What shall be done now that the war is over? Shall we allow the animosities which have been aroused to continue and bar the men of the central nations from membership in international scientific societies, or shall we forget political differences and get back as soon as possible to the prewar basis so far as scientific gatherings are concerned? It seems to us that the latter is the only true course to follow. We are in entire agreement with the following words of Professor E. C. Pickering, written only a month before his death to Professor Elis Strömgren, director of the Copenhagen Observatory, who quotes them in an "In memoriam" to Professor Pickering published in the *Astronomische Nachrichten* February, 1919.

"I do not approve of the plan of establishing international societies in which the scientific men of the central and neutral nations are not included, at least in the case of such subjects as have no relation to the war. Astronomers, for example, ought to be able to carry out international work by correspondence, even if it is not desirable at present to hold meetings. I am anxious to know how far European Observatories have suffered and what is likely to be their condition when the peace treaties are actually signed. All of this seems a little premature, but large delays are likely to occur. I believe that many astronomers agree with me that we should make every effort for the advance of our science, regardless of personal or national considerations."

Parallax of the Orion Nebula.—In the April, 1919, number of the *Publications of the Astronomical Society of the Pacific* Mr. William H. Pickering revises a former estimate of the parallax of the Orion Nebula, now making the parallax 0".0020, corresponding to a distance of 500 parsecs or 1600 light-years. Professor Kapteyn had obtained 0".0054 for the same quantity. Neither of these results is based upon direct measures, but upon theoretical considerations of the brightness and size of the stars which lie within the limits of the nebula.

Radio Time Signals.—In response to an inquiry the Acting Secretary of the Navy states that "effective April 15, 1919, the restrictions on receiving stations will be removed. The operation of receiving stations was forbidden by an Executive Proclamation dated April 6, 1917, and this Proclamation will remain in effect with reference to transmitting stations and to receiving stations handling commercial business.

"In connection with the reception of time signal your attention is invited to the fact that the signals transmitted by the Naval Radio Station at Washington will remain at the same hour throughout the year, irrespective of the Daylight Saving Law. The signals transmitted by all other Naval radio stations in territory affected by this law will be advanced one hour during the summer."

Optical Glass made in America.—In the April 1919 number of the *Publications of the Astronomical Society of the Pacific* Dr. H. D. Curtis has a very interesting and important article on "Optical Glass," dealing with the problem which was put up to manufacturers of optical glass in the United States by the breaking out of the great war. Prior to August, 1914, practically all our optical glass came from a few German, English and French makers. The war at once cut off the German supply and practically all the English and French product was requisitioned by those nations for their own military needs.

Although many difficulties had to be overcome, as a result of the efforts of several optical firms, aided by the experiments of the United States Bureau of Standards Laboratory and the Geophysical Laboratory of the Carnegie Institution, the emergency was successfully met and optical glass of excellent quality was soon being made in quantities sufficient to meet the multifarious needs of our army and navy. When the armistice was signed the total production was probably in the neighborhood of twenty tons per month.

At the close of his article Dr. Curtis adds this paragraph:

"What of the future of this industry in the United States? Here commercial and financial considerations will undoubtedly prove of paramount importance.

At least two of the firms at present manufacturing optical glass propose to continue in the field; several others, which have engaged in the work to assist in meeting war needs, will cease manufacture soon. There is little profit in this product, and some patriotism will have to be combined with the profit or loss of the balance sheet. It is not, and never will be, a very large industry, important as it is for the scientific independence of the country. We are making in America as good optical glass as that of any foreign firm. Can those firms which will continue in the production of American optical glass meet the post-war competition of foreign cheaper production? This is a matter for the earnest consideration of those who desire to see this country self-contained and independent in this essential and important industry. It appears certain that this country should never again be permitted to become entirely dependent upon foreign optical glass; we can and will make our own."

A Combination Sidereal-Solar Clock.—Professor Elis Strömgren, director of the Copenhagen Observatory, and Engineer Jens Olsen have constructed a clock which shows sidereal time and mean solar time at the same instant, which will be a great convenience for all who are required to use the two times, especially astronomers, geodesists and seamen. The clock has four dials, one for each of the two kind of hours, one for the minutes with two hands, the one hand gaining on the other in the ratio of 1 part to 365, and one dial for the seconds of mean time. The two sets of hands can be adjusted independently, so that one may be kept on local time and the other on the time of any chosen meridian, or both may indicate the times of any chosen meridian. The clock is a little larger than the ordinary watch but may be easily carried in one's pocket. The clock is manufactured for sale by Cornelius Knudsen, H. M. Instrument Maker, Copenhagen, Denmark.

The Cawthron Institute.—The Cawthron Observatory at Nelson, New Zealand, to which reference was made in POPULAR ASTRONOMY some months ago, is to be but a small part of a larger institution known as the Cawthron Institute, for which the late Mr. Cawthron left in trust a sum which now amounts to £213,000, together with land at Annesbrook valued at £5075 and Observatory land valued at £500. Mr. Cawthron was very much interested in establishing a solar observatory in Nelson and had purchased the land for the site before his death. In the newspaper clipping from which we gather these facts it is stated that "Dr. Hale, of Pasadena, has promised to prepare a plan of suitable instruments, similar to that which he is preparing for Italy, and which would be inexpensive and yet enable observations to be made, the results of which could be worked out in America and be of the greatest value to science. The trustees are disposed to favorably consider the matter."

It is said that the trustees of the Cawthron Institute propose to establish, within seven years, three minor scholarships of £315, two Cawthron scholarships of £300 and two fellowships of £500, these to be open to all New Zealand.

It is suggested also that the Government, through the Board of Science and Industry, might assist the Cawthron Institute with grants and subsidies in those cases in which large scale experiments of an expensive type had to be undertaken.

The policy of the Board of Science and Industries, if we read aright, is a very liberal one, namely to subsidize liberally all research work in New Zealand, whether carried out in Government laboratories, university colleges, research in-

stitutes, or by private individuals. The money would be paid by direct grants or in the form of fellowships or scholarships to be held at specified institutions for specific purposes.

Is there not a suggestion here worthy of consideration by the proper authorities in the United States?

A Limiting Absolute Magnitude for Cepheid Variables.—In the summary to his tenth paper on "Studies based on the colors and magnitudes in stellar clusters" (*Astrophysical Journal* **49**, 96, March 1919), Mr. Harlow Shapley says: "The absolute photographic magnitude —0.2 defines a limit of stellar luminosity at which the liability to Cepheid variation suddenly stops. All known variables of the class appear to surpass this limiting brightness, which is probably coincident with a turning-point in the development of the internal structure of the star. Whether or not analogous dynamical changes occur, regardless of variability, at the same epoch in the evolution of luminosity for all giant stars, has been discussed for several globular clusters with the aid of luminosity-curves derived from the magnitudes of 5000 stars . . . . Confirming earlier work, the final results for this cluster (Messier 3) show that the highly luminous stars are red, that the fainter ones are blue. The infrequency of cluster-type variables in the Hercules cluster (Messier 13) is compensated for by the richness of extremely blue stars at the median magnitude."

American Association of Variable Star Observers.—At the invitation of Mr. David B. Pickering, the next meeting of the Association will be held at his home, 171 South Burnett Street, East Orange, New Jersey, at eight o'clock on the evening of Saturday, May 3, 1919.

Reports of several committees, including that on nominations, will be submitted, and special action will be taken on the death of the first Honorary Member and Patron of the Society, Professor Edward C. Pickering.

A Method of Determining the Diameters of the Heavenly Bodies from a study of their interference fringes is described by Maurice Hamy in the last Annuaire of the Bureau des Longitudes. The author shows how this method may be applied to measurements of such bodies as satellites and minor planets and gives determinations for several of these bodies. He expresses the opinion that with the new 100-inch reflector at Mt. Wilson it might be possible to measure the angular diameters of the first magnitude stars by this method. (*Scientific American* April 19, 1919.)

Exhibit of Eclipse Photographs.—Miss Harriet M. Parsons of the Vassar College Observatory has very kindly sent the following account of an Exhibit of Eclipse photographs in New York.

At the American Museum of Natural History in New York City, fifteen interesting eclipse photographs are being exhibited. Two of the plates show instrumental equipment, one gives the coronal spectrum, and the others portray prominences and varying extents of corona. Each photograph is accompanied by a few brief notes stating important details such as length of exposure, instrument used, and name of observing party. As the work of many of these expeditions has been described in POPULAR ASTRONOMY, a brief description will suffice here.

The first plate shows the corona as photographed with a 140 ft. camera by the observers from the Smithsonian Institution at Wadesboro, N. C., on May 28, 1900. It is said to be the largest eclipse photograph ever taken.

The remaining photographs give results of the eclipse of June 1918, and were taken by expeditions from the Lick Observatory stationed at Goldendale, Washington; the U. S. Naval Observatory, at Baker, Oregon; the Mt. Wilson Observatory, at Green River, Wyoming; the Sproul Observatory, at Brandon, Colorado; and the Lowell Observatory, at Syracuse, Kansas.

Four excellent plates are exhibited by the Lick Observatory, one of which shows instrumental equipment: a 40 ft. camera, a spectrograph, and the Vulcan-Einstein Cameras. The other three are photographs taken with the 40 ft. camera with exposure of 1/3, 4, and 2 seconds respectively. They vary in the extent of coronal streamers shown, the definiteness of the inner corona, and the sharpness of the prominences.

The U. S. Naval Observatory has sent two photographs, each of 5 seconds exposure taken with their 65 ft. camera, showing the inner corona and prominences very clearly. See *P. A.* XXVII p. 1.

One plate from Mt. Wilson gives the most extensive corona exhibited, showing streamers extending nearly a diameter on either side of the solar image.

Two plates from the Sproul Observatory give exposures of 2 and 45 seconds respectively taken with the 62.5 ft. camera. The former shows bright prominences and excellent detail of the inner corona, and the latter shows an extensive corona only exceeded by the Mt. Wilson photograph. The arching of the coronal streamers over the prominences is especially noticeable. See *P. A.* XXVI p. 481; XXVII p. 36.

The last five plates are from the Lowell Observatory. The first is an exposure of 35 seconds taken with the 38 ft. camera, showing much detail in the extensive corona. The second gives the inner corona and prominences as photographed during the last seven seconds of totality. The next photograph gives in detail the large centipede-shaped prominence on the west side and is evidently an enlargement of part of the preceding photograph. Another plate shows the instrumental outfit, and the last is a spectrogram of the corona taken at East Lynne, above the Lowell station. See *P. A.* XXVI p. 462; XXVII p. 33.

Anyone in the vicinity of New York will find the exhibit well worth seeing. A painting of the eclipse by Mr. Butler, presented by Mr. Adams, is being reproduced by special color process for presentation to various observatories and therefore is not included in the exhibit at present.

Vassar College Observatory,
Poughkeepsie, New York.
April 11, 1919.

The Reform of the Calendar.—In Vol. XX, 1912, p. 232 of POPULAR ASTRONOMY we printed an article by Dr. Ralph E. Wilson, reviewing the proposals which were at that time being considered for the reform of the Gregorian calendar. In that article the plan of Professor Grosclaude, of Geneva, Switzerland, was explained with approval. This plan is essentially to divide the year into four quarters, each containing three months of 30, 30 and 31 days respectively, 13 weeks or 91 days. This would make 364 days. To make up the extra day in common years it was proposed that New Year's Day should be a day apart from the week, having no other name than New Year's Day. In leap years an extra

day, without name in the week, might be inserted between June 31 and July 1, known only as Leap Day. By this plan the days in the week would have the same numbers in both month and year for all succeeding years, and the keeping of accounts extending over a period of years would be much simplified. The arrangement of calendars for years ahead would be exceedingly simple.

But it takes more than simple arguments to get people out of the ruts they have followed for centuries, and very little attention has been paid to the calendar reformers.

The present would seem to be a favorable time to press the question of an immediate change in the calendar and its adoption by all nations, since the shock of the great war and the stress of peace negotiations and the formation of a League of Nations has jarred all peoples loose from their traditions and prejudices and made them willing to accept many changes which they would not have thought possible before.

The matter has recently been discussed in the French Academy of Sciences, and papers presented to the Society by Messrs. G. Bigourdan and H. Deslandres have been published in the *Comptes Rendus*. We present below the paper by M. Deslandres, translated from the French by Professor James P. Bird, of Carleton College.

It will be seen that the plan here recommended is essentially that of Professor Grosclaude with the substitution of Peace Day as the extra day in ordinary years.

PAPER BY M. H. DESLANDRES ON THE REFORM OF THE CALENDAR.

Jan. 20, 1919.

At the previous sitting, M. Bigourdan presented a very interesting paper on the improvement of the Julian and Gregorian calendars. He enumerates their imperfections and demands immediately a better distribution of the days of the year, a distribution which is to make as equal as possible the months and also the quarters.

Now the points enumerated have been the subject of proposals and discussions during the last decades. In particular, I myself raised the same questions in this Academy in February, 1913, offering to bring them before the International Association of Academies which was to have a meeting that same year in Petrograd. The offer was accepted and a succinct note summing up the improvements to be considered was adopted by a special Commission appointed for this purpose, and by this Academy. The note was presented to the International Association on the seventeenth of May, 1913, and adopted by it. The following measures were voted (14 votes for, one vote against, and four not voting.)*

"The International Association of Academies decides on the creation of an International Calendar Commission, whose duty is to be the studying of the questions relative to the unification and simplification of calendars and the fixing of the festival of Easter. The members of this Commission will be appointed by each of the associated Academies, in the ratio of two from each Academy, without their belonging necessarily to it, in conformity with article 18 of the Statutes. The Calendar Commission, whose President shall be from the leading

*The representative from Holland voted against the measure. Those not voting were the representatives from Italy, Denmark, and from the Universities of Leipzig and Göttingen.

Academy during the period (1914-1916), will make a report on its findings at the next session of the International Association after having got in touch, if it is deemed desirable, with the ecclesiastical authorities interested."

The leading Academy for the period 1914-1916 was the Academy of Berlin, and the war prevented the execution of the measures taken.

During the same year, 1913, on March 29, at the International Congress of Geography at Rome, our colleague M. Lallemand and M. Lecointe, correspondent of our Academy, proposed the reform of the calendar, and provoked a very interesting discussion.

In June, 1913, at Brussels, the World Congress of International Associations demanded in a special petition the intervention of the Governments for the choice of a universal calendar.

The Chambers of Commerce also presented their petitions and their support. The fourth International Congress of Chambers of Commerce, and of Commercial and Industrial Associations, meeting in London in 1910, the fifth Congress held in Boston in 1912, and the sixth held at Paris in 1914 have emphasized the great advantages of a simplified calendar for all transactions, and proposed its adoption by an international diplomatic conference.

Finally, in 1914, an International Congress for the reform of the calendar met at Liege, and, taking the question up in earnest, expressed the hope that the new calendar would be perpetual, and that it might assure an invariable agreement between the days and the dates of the year.

In the four years that preceded the war, the problem of the calendar was attacked from all sides, and made an international matter. Now the solutions proposed have all agreed, at least in part, with the conclusions of a former inquiry into the question, which was conducted carefully from 1884 to 1887, by the Astronomical Society of France, and under conditions which it would be well to recall. In 1884, Sir Richard Wallace and Abbé Croze, chaplain of la Roquette, asked M. Flammarion to organize a great contest for the choice of the best calendar and put at his disposal the sum of 5,000 francs for the final distribution of prizes.

The contest took place and 50 memoirs were presented. After an excellent statement by M. Fouché, the first prize was awarded in 1887 to M. Armelin who proposes:

1. A year composed of four equal quarters, and of one or two supplementary days. The quarter comprises 13 whole weeks with 91 days, (two months of thirty days and one of thirty-one).

2. The breaking of the continuity of the week for the intercalation of the supplementary days, in such a way that the same dates will always correspond to the same days of the week.

The majority of the authors and finally the special Congress of Liege in 1914, adopted the two preceding improvements, modifying them only slightly.

On the other hand M. Bigourdan accepts only the first improvement, which will certainly be easily admitted by all; he rejects the second, based on the continuity of the week.

But the second improvement is the most important and the most useful; his rejection of this deprives the reform of the greatest part of its value. It is necessary according to my opinion to maintain it absolutely, for this alone is capable of assuring a perpetual and invariable calendar with the maximum of convenience and of simplicity. To be convinced of this, it suffices to glance at the

following Table, which, constructed with the breaking up of the week, can, in spite of its restricted dimensions, replace all the calendars, variable from one year to another.

PLAN FOR A PERPETUAL INVARIABLE CALENDAR.

First half	First quarter	January	February	March	
	Second quarter	April	May	June	
	Peace Day				
Second half	Third quarter	July	August	September	
	Fourth quarter	October	November	December	
	Extra Day (Leap year)				

Invariable Quarter																							
	Monday	1	8	15	22	29		6	13	20	27			4	11	18	25						
	Tuesday	2	9	16	23	30		7	14	21	28			5	12	19	26						
	Wednesday	3	10	17	24		1	8	15	22	29			6	13	20	27						
	Thursday	4	11	18	25		2	9	16	23	30			7	14	21	28						
	Friday	5	12	19	26		3	10	17	24			1	8	15	22	29						
	Saturday	6	13	20	27		4	11	18	25			2	9	16	23	30						
	Sunday	7	14	21	28		5	12	19	26			3	10	17	24	31						

In this calendar, the normal year of 365 days comprises two identical semesters of 182 days, separated by an intermediary day, not dated, set outside of the week and called, for example, Peace Day.

The four quarters of this year and of every year are identical and each comprises 13 whole weeks or 91 days.*

On Leap Years, a second supplementary day is added at the end of the year, also set outside of the week and called *Leap Day*.†

This very simple calendar is easily held in mind; it makes it possible to calculate immediately the date of a day of the week or the day of the week which corresponds to a given date. It will assure everyone an economy of thought, as I wrote my note of 1913.

The advantages are much superior to the inconveniences noted. Religious objections are to be expected, but they are not insurmountable; and the annoyance imposed on the few people who verify the dates is small as compared with the multiple facilities assured to all human kind.

A third improvement, less important, but not negligible, is a moving of the beginning of the year, which will put the four quarters in better accord with the astronomical seasons.‡ The first day of the year, for various reasons, has varied considerably since the beginning of the Christian era;§ it will be a good idea to give it an astronomical basis and to make it coincide with a solstice or an equinox. M. Flammarion has proposed the vernal equinox, and H. Hétier, for spe-

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*The month of 31 days is the third month of the quarter as in the plans of MM. Flammarion, Grosclaude, Philip, Armand Baar. In the plans of MM. Armelin, Henin, Bigourdan, etc., the month of 31 days is the first month.

†In the table, the second supplementary day is at the end of the year; it is natural, *a priori*, to place the extra day after all the others. Taking everything into account, it seems better to place it at the beginning of the year. Each supplementary day, for practical purposes, will have to be identified with some month and some quarter, and, as it is necessary to avoid months of 32 days, one is led to include the peace day in the month of July and the extra day of leap year in the month of January.

‡The astronomical seasons are unequal (from 89 to 93.6 days); practically, they would coincide with the quarters which are equal or within a day of being so, counting the extra days.

§The first day of the year, fixed on the first of January by Julius Caesar, was, for unessential reasons, set at Christmas by Charlemagne; later it was carried forward to Easter. In the Republican calendar it was at the autumnal equinox.

cial reasons has proposed the autumnal equinox or even the first of September. In my opinion, the best beginning is the winter solstice (the present 22 of December), which is the point of departure for the days of increasing length in our hemisphere, and the beginning of a new cycle of vegetation. Furthermore, the minimum of temperature does not coincide with the solstice, which is the day of the minimum of light, but follows it some 25 days in our latitude; this is why the astronomical winter is for us the coldest season.

The fixing of the festival of Easter is also desirable, and the second or the third Sunday after the vernal equinox has been proposed; but a preliminary agreement with the religious authorities is necessary. This improvement can be postponed and decided after the three preceding.

And so the question is quite ripe and ready for a definite decision. Heretofore, it has been examined only by international Congresses, belonging to special groups (men of science or of business, etc.); but it is of an absolutely general order and interests all men. It is proper to bring it before the International Association of Governments, that is to say before the League of Nations which is being formed at the present moment.

In my opinion, the Academy would do well in taking it under its patronage and in recommending it to the great international assemblies which are now being organized at Paris for the establishment of a durable peace among nations. If we go back to the past, we will find that the successive changes in the calendar have coincided with the great events in history; the moment seems propitious for the complete and definite solution of the problem.

To Halley's Comet.

"Many centuries ago comets were looked upon as 'Fireballs' flung by an angry God, and even as late as the 17th century facts that were beginning to be known about them were kept from students, lest their religious beliefs be disturbed."

"Halley's periodic comet appeared in 1910, and was last seen before that in 1835."

Thou "Wanderer" out in the vast Unknown,
When next upon thy path around the sun
Thou dost return, how many will have run
Their race who saw thee last, and youth have grown
To age, and many changes will be here!
Such progress has the mind of man achieved
In knowledge of the heavens, 'tis scarce believed;
Yet more 'twill know when next thou shalt appear.
While thou, returning, wilt thy path pursue
For centuries, and many millions will
Thy coming watch and recognize, until,
At last, thou, too, shalt disappear from view;—
Worn out, dissolved, and scattered far through space,
No more shall men behold thee in thy place!

—ALICE BERLINGETT.

Norfolk, Virginia, April, 1919.

His Status.—"What do you think they did to my Willie at the hospital, ma'am, They cut out all his asteroids." "Then I suppose he is now their star patient."